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HIGH VOLTAGE TESTING: TEST PROGRAM REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The High Voltage Design Guide and High Voltage Specifications and Tests Documents referred to in this report pertain to high voltage/high power airborne equipment. A test plan was designed to evaluate and verify test parameters specified in these documents. This was done by writing detailed test procedures, obtaining representative test samples, and testing the specified parameters. In addition, a standard test fixture and corona-free 150 kV, 400 Hz power supply was specified, evaluated, and delivered for use with a partial [illegible]arge test set.

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FOREWORD

Presented herein is the Boeing Aerospace Company's Test Report covering work accomplished on Contract F33615-79-C-2067 for the period of September 24, 1979 through April 1, 1982. This contract is being performed for the Aero Propulsion Laboratory Air Force Wright Aeronautical Laboratories, Air Force Systems Command, Wright-Patterson AFB, Ohio. The program is under the technical direction of Daniel Schweickart, AFWAL/POOS-2.

Personnel participating in this work for the Boeing Aerospace Company were W. G. Dunbar, the technical leader, and S. W. Silverman, the program manager.

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1.0 PROGRAM OBJECTIVES

The objectives of this program are as follows:

a. Perform high voltage tests on capacitors, cable assemblies and parts, and coils.

b. Design, fabricate, and evaluate a high voltage standard test fixture to be used for measuring the void content in various high voltage insulation systems.

c. Specify and procure a 150 KV, 400 Hz power supply for partial discharge measurements.

d. Update the Tests and Specifications criteria documents completed in U.S. Air Force Contract F33615-77-C-2054 to include the findings from the test article evaluations.

e. Develop a high voltage generator test procedure.

f. Update of the Airborne High Voltage Design Guide completed on U.S. Air Force contract F33615-76-C-2008.

g. Develop a Spacecraft High Voltage Design Guide.

2.0 SCOPE

The major tasks reported in this Test Report are:

- High-voltage power supply verification testing at Hipotronics and Wright-Patterson AFB.
- Selection and testing of test articles
- High-voltage test plans for the test articles
- Design and verification testing of the standard test fixture

3.0 BACKGROUND

In previous contracts, high-voltage test and specifications criteria documents were written for U.S. Air Force airborne power supplies and components which supply megawatts of power at tens of kilovolts to high-power/high-voltage systems. A generalized power source is shown in Figure 3.0-1 for a turboalternator system. However, the turboalternator can be replaced with a MHD power supply. Emphasis has been placed on minimum weight and volume airborne equipment, which imply compact systems with high density packaging.

The specifications and tests criteria document prepared under contract F33615-77-C-2054 do not have all the electrical, mechanical, and environmental requirements and test parameters for high-voltage and/or high-power applications. It is the purpose of this program to evaluate the parameters listed in the applicable criteria documents, by writing detailed test procedures and then test hardware to the specified parameters. Following completion of the test program, the Test and Specification Criteria Documents will be updated to reflect the findings of this test program.

A 150 kilovolt Partial Discharge Detection system was also developed during contract F33615-77-C-2054, and was installed at the Aero Propulsion Laboratory, Air Force Wright Aeronautical Laboratories at Wright-Patterson AFB, Ohio. Two new components are being added to this system: a 150 kV, 400 Hz power supply, and a Standard Test Fixture for testing A/C systems, components, and electrical insulation. The addition of these two units to the present direct voltage Partial Discharge Detection System at AFWAL/POOS will give the U.S. Air Force a complete facility for testing electrical properties of materials, components, and systems used in present and future high-voltage and/or high-power systems.

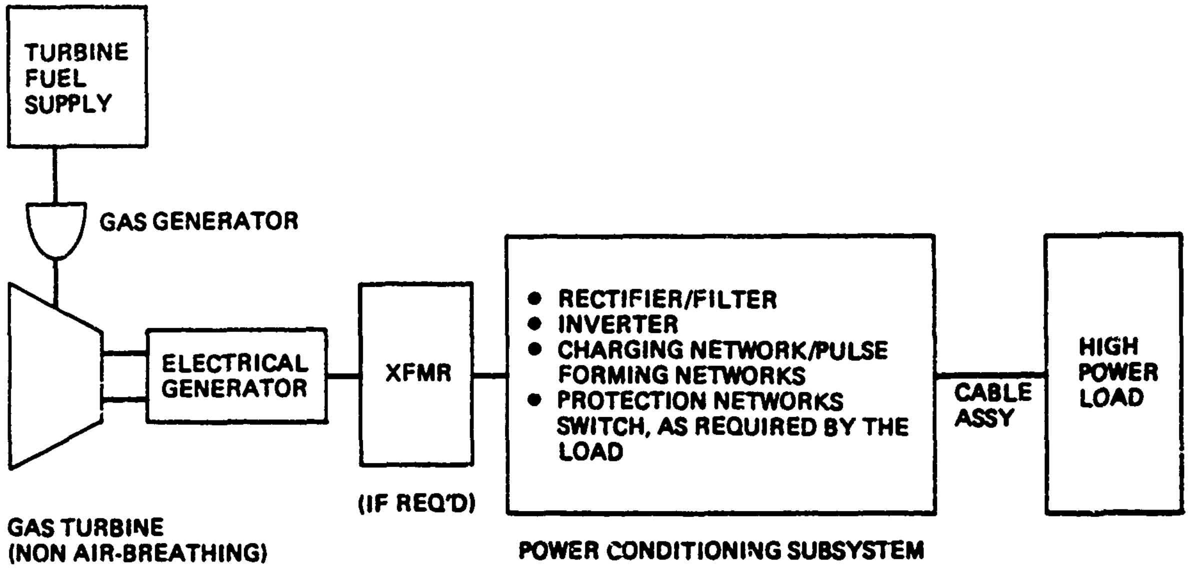


Figure 3.0-1: High Voltage/High Power Airborne System

4.0 HIGH VOLTAGE POWER SUPPLY

4.1 Description. The U.S. Air Force Wright Aeronautical Laboratory purchased a Partial Discharge Detection System capable of detecting 0.1 to 10,000 picocoulombs partial discharges within direct voltage and alternating current insulation systems. The system is equipped with the following components:

- Partial discharge detector
- Power separation filter
- Calibration Signal Coupler
- Voltmeter
- Isolation Buffer
- Noise Filter
- Grounding Wand
- Multichannel Analyzer

A system schematic diagram for the facility is shown in Figure 4.1-1.

The dc noise filter is designed to operate with dc applied. The power separation filter/detector is designed to operate with either high-voltage ac or dc. To broaden system capability, a high-voltage ac power supply (not shown in Figure 4.1-1) was purchased with the following specified electrical parameters and components:

HIGH VOLTAGE TRANSFORMER

Input Voltage: 208 Volts, 400 Hz, 1 Phase

Output: 150 KV, 20 KVA, 400 Hz, 1 Phase, 1 hour duty cycle

150 KV, 15 KVA, 400 Hz, 1 Phase, continuous

Separation Filter Capacitance: 20 Picofarads

Oil Filled - Texaco #55 uninhibited transformer oil or equivalent

Life: 10,000 hours in 10 years

1 year guaranteed

Noise level shall be less than 5 PC at 150 KV

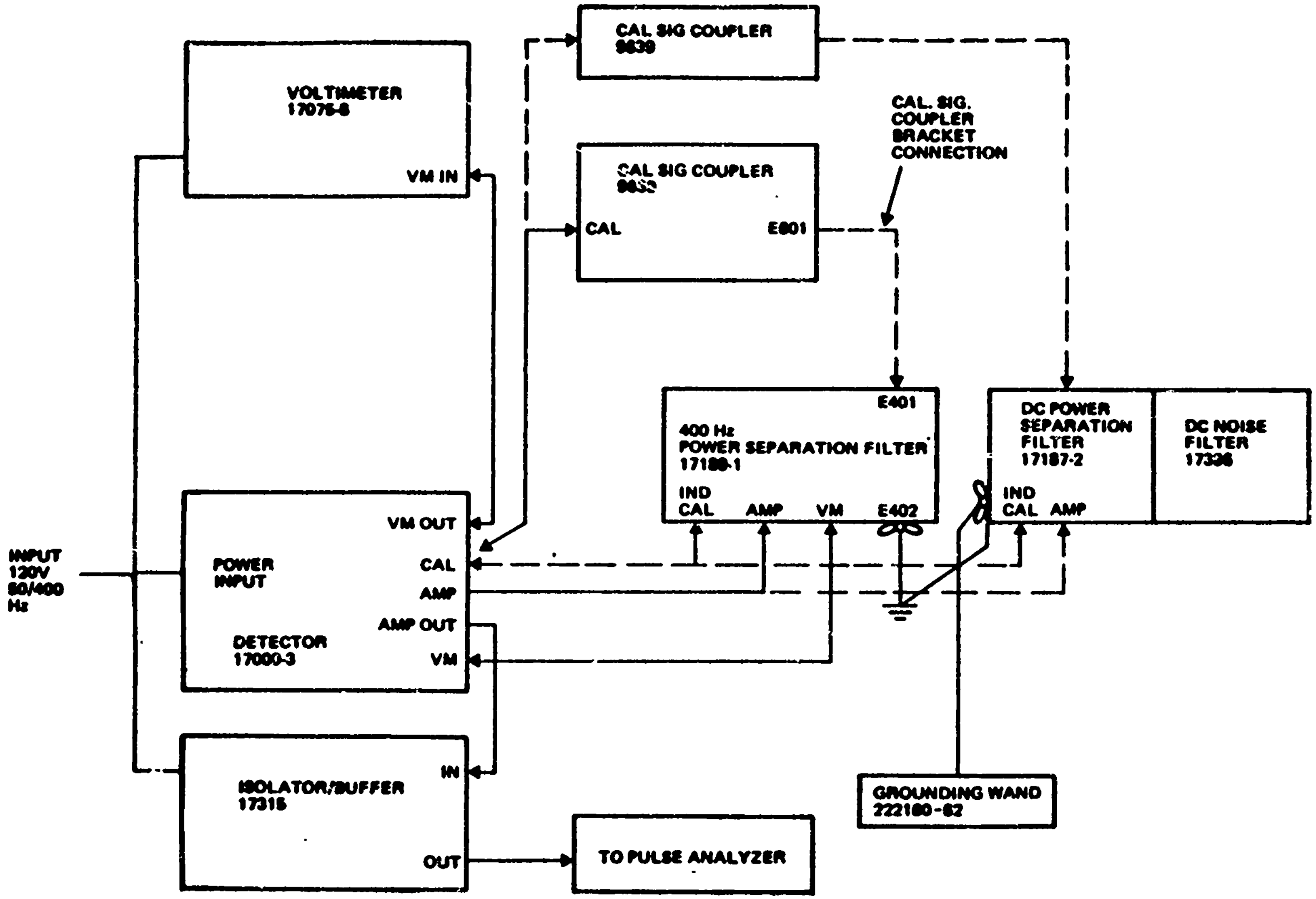


Figure 4.1-1: Corona Test System Schematic

CONTROLLER

Input: Controls: 120 Volts, 60 Hz, 1 Phase,
Power: 208 Volts, 400 Hz, 1 Phase, 120 Amperes

Overcurrent protection

Meter relay to preset output voltage

Voltage rise: 30 seconds and/or 300 seconds

Voltage vernier: 10 KV at voltages between 10KV and 140KV

Power line filter

Console writing shelf

Interconnect cables

Power cables

Instruction manuals

Manufacturer: Hipotronics

4.2 Qualification Test. A qualification test was made at the manufacturer's facility (Hipotronics). Following qualification and inspection, the unit was packaged and shipped to AFWAL where it will become a part of the Partial Discharge Detection System.

4.2.1 Test. The high-voltage power supply and controller were connected to the output of a 400 Hz generator. As the controller voltage was increased from 95 kV to 150 kV, corona readings, input voltage, and current readings were taken. The test results are shown in Table 4.2-1.

TABLE 4.2-1: HV POWER SUPPLY TEST DATA

Transformer Output kV	Corona PC (max.)	Controller Input 400 HZ Volts	Amperes
96	1.0	217	33
124	2.0	208	57
145	4.0	218	85
150	4.5	215	84

A check of the voltage vernier was made with the output set at 100 kV.

Boost	100 to 129 kV
Buck	100 to 78 kV

The controller includes the following operational instruments and controls.

Voltmeter: ac multirange
Ammeter: Primary (transformer) current: Calibrated in secondary milliamperes
Rate of rise control:
28 seconds (maximum) to full voltage
300 seconds (minimum) to full voltage
Separation filter circuit output impedance: 75 ohms at 70 kHz

4.2.2 Auxiliary Components. A three-phase, 400 Hz, 125 Kva, 208/115 volt, ac generator or a variable frequency power source will be used to supply the low-voltage input ac energy requirements for the high-voltage power supply. A delta-connected, balanced resistor network may be connected to the primary of the transformer to correct the generator power factor as shown in Figure 4.2-1. The series-connected inductor has a two-fold function: 1) power factor correction, and 2) a line filter. The series inductor is tapped for inductance of 0.5, 1.0, and 2.0 millihenries, and is designed for continuous operation at 100 amperes and 250 volts ac.

Data collected during the qualification test were taken at the manufacturer's facility with line filters connected to each side of the transformer primary winding. The data are shown in Figure 4.2-2 and Table 4.2-2 without the delta loads connected.

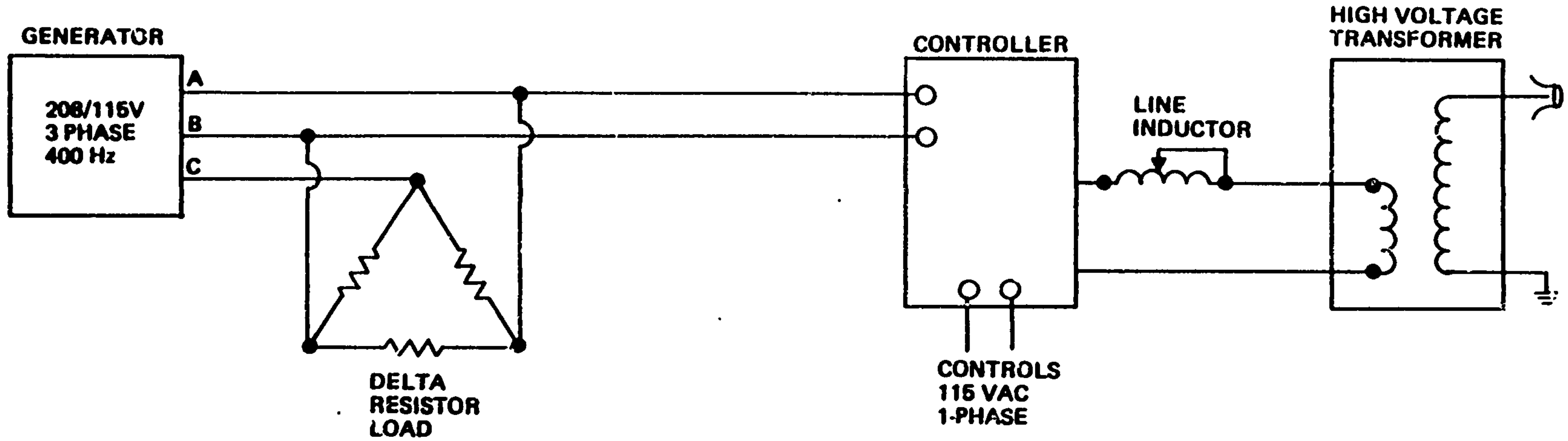


Figure 4.2-1: Power Supply and Auxiliary Components

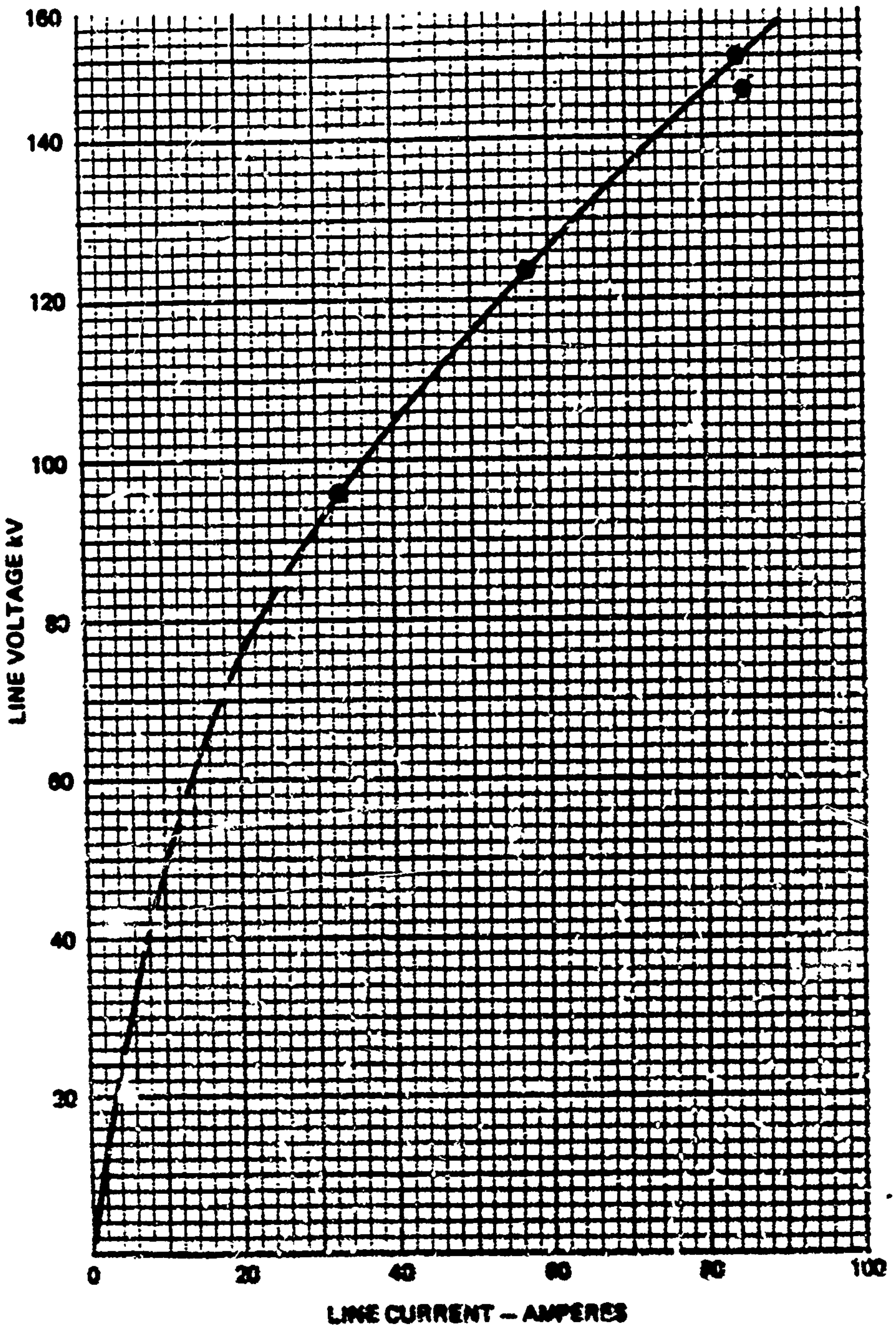


Figure 4.2-2: Power Supply Electrical Input Requirement (400 Hz With Line Filters)

TABLE 4.2-2: POWER LINE REQUIREMENTS
(400 Hz with line filter)

Voltage kV	Line Current Amperes	Line Volts	Impedance Ohms
96	33	217	6.56
124	57	218	3.82
145	85	218	2.565
150	84	215	2.56

5.0 STANDARD TEST FIXTURE

5.1 General. The information and procedures contained within the instruction manual for use with the fixture have been prepared to assist the user in connecting, operating, and maintaining the high voltage Standard Test Fixture. The Standard Test Fixture is to be used as a part of the Partial Discharge Detection System at the Wright-Patterson AFB, Oh., Area B, Building 450, Room D109. Care has been taken to include an electrical interlock for safety and specify standard ASTM-D149 electrodes for dielectric strength, breakdown, and partial discharge measurements.

Measurements may be taken with the specimen either submerged in a liquid, encapsulated, or in air. The test fixture was fully tested before shipping. Proper use and maintenance of the test fixture, as outlined herein, will aid in keeping the test fixture at peak performance and prolong its useful life. A safety practices paragraph is included as part of the operator's instruction manual to be followed when using this equipment.

5.2 Description. The test fixture is designed to comply with the latest requirements set forth in ASTM-D149 and ASTM-D3382 for standard test methods of testing electrical insulating materials for breakdown, dielectric strength, and partial discharges.

Two plug-in test fixtures, purchased from Associated Research, Inc., Skokie, Illinois, are available for testing electrical materials. These fixtures are designed so that they can be easily and quickly changed.

Standard electrodes per ASTM-D149 were also purchased for these fixtures. The fixture part numbers and descriptions are shown in Table 5.2-1.

Table 5.2-1: Test Fixtures and Electrodes

Description	Associated Research, Inc. Part Number
Test Fixture	31550
Test Chamber	31560
2-inch electrode, upper	31867
2-inch electrode, lower	31884
1-inch electrode, upper	31873
1-inch electrode, lower	31883
1/4-inch electrode, upper	31870
1/4-inch electrode, lower	31876

All three electrode sizes are designed to fit into the test fixture. A test sample may be tested either in a gas between the electrodes or in a liquid by inserting the test fixture in the test chamber as shown in Figures 5.2-1, 5.2-2, and 5.2-3. The test fixture and chamber are housed in a bench-mounted steel cabinet measuring 25½ inches high, 21½ inches wide, and 18½ inches deep. A built-in test compartment in the upper part of the cabinet has inside dimensions of 12½ inches high, 17½ inches wide, and 16 inches deep. Hinged double doors are made of clear plexiglass for full view of the article under test, and to provide access to the test compartment. A double interlock system attached to the two doors can be series-connected to the partial discharge detection system interlock system. High-voltage and ground leads are connected to the bottom of the test compartment. These leads will be connected to the Partial Discharge Detection System. Test fixtures, purchased in the future, may be connected to the two high-voltage receptacles mounted through the bottom of the test compartment. A photograph of the Test Fixture Assembly, with the test fixture installed, is shown in Figure 5.2-1.

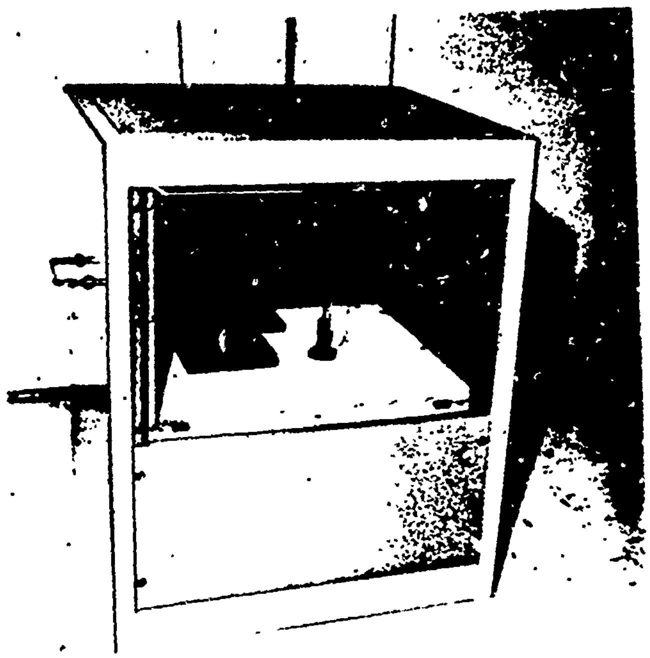


Figure 5.2-1: High Voltage Test Fixture

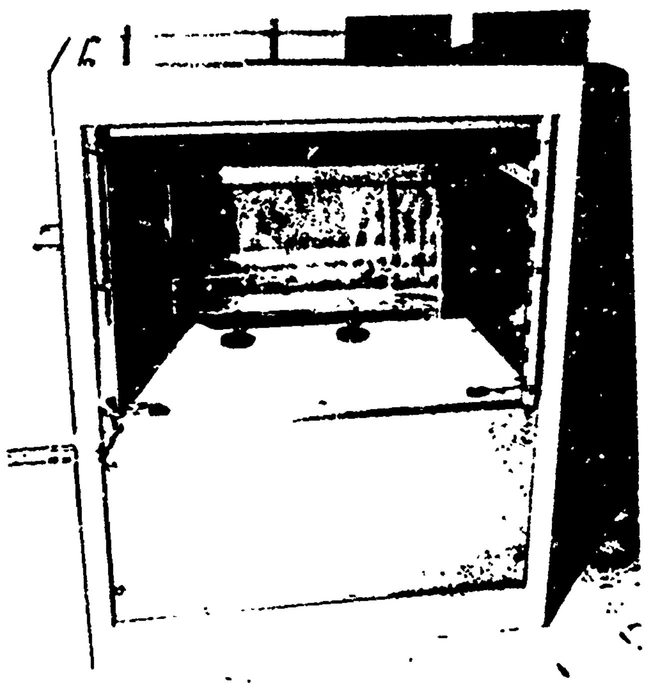


Figure 5.2-2: Test Chamber

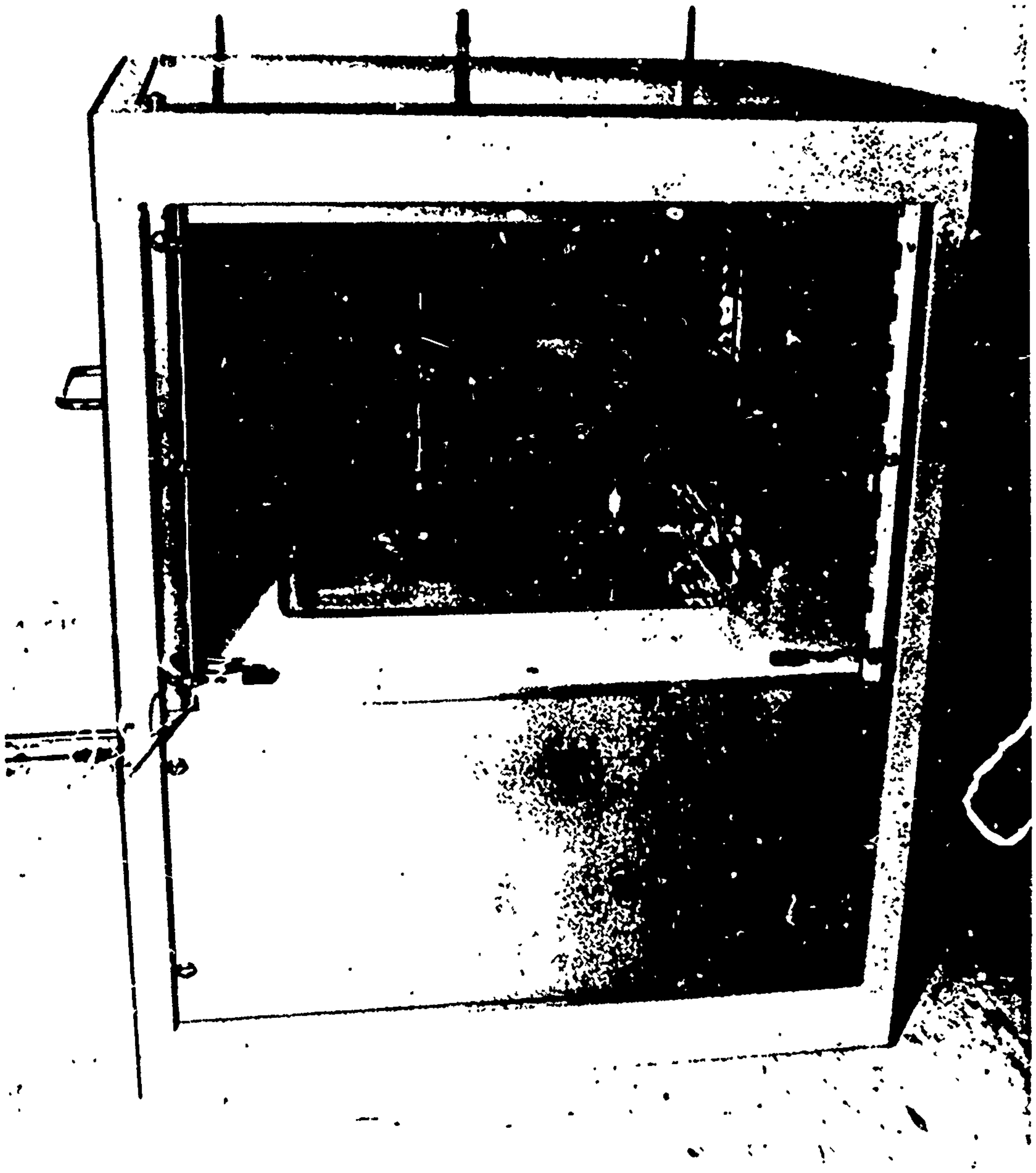


Figure 5.2-3: Electrodes Installed in the Test Chamber

5.2.1 Test Compartment. The test compartment houses the high voltage terminations, materials test fixture, and material being tested, augmenting safety for the operator and other personnel. This safety feature permits the instrument to be used in the laboratory, without the need for roping off the area or erecting a test cell.

Two, hinged, clear plexiglass doors provide access to the test chamber. Both doors are equipped with safety interlock switches that can be connected in series with the Partial Discharge Detection System interlock system to disable the high-voltage control circuit when one or both doors are open. The doors are held in the closed position by magnetic latches.

High-voltage terminations are made of two large banana jacks mounted on the bottom plate of the test chamber. These jacks receive the banana plug terminations on the materials test fixtures, providing high-voltage connection to the fixture electrodes. The jacks were corona free to 30 kV dc without corona nuts and special high-voltage wire.

5.2.2 Cables. A flexible copper braid ground return is connected to the left terminal. This ground return must be connected to the Partial Discharge Detection System separation filter ground. The insulated high-voltage lead connected to the right terminal must be connected to the high-voltage termination of the separation filter. Care must be taken to centrally locate the high voltage wire between all frame edges on the back side of the test fixture, to prevent corona and arcing to the frame.

5.3 Principles of Operation.

CAUTION
TO INSURE PERSONNEL SAFETY, THE INTERLOCK SWITCHES MUST BE INCORPORATED INTO THE EXTERNAL PARTIAL DISCHARGE DETECTION SYSTEM CIRCUITRY, AND THE HIGH VOLTAGE LEAD MUST BE GROUNDED AT ALL TIMES THAT THE TEST FIXTURE IS INACTIVE.

5.3.1 General. The following procedure has been prepared to acquaint the user with the fundamental operating procedure of the test fixture and to assist in obtaining the maximum performance from the system which includes the Partial Discharge Detection System. For best results, ASTM or military specified procedures must be adhered to.

5.3.2 Preliminary Preparation.

CAUTION
THE VOLTAGES PRESENT IN THIS SYSTEM ARE DANGEROUS TO LIFE. USE EXTREME CARE WHEN OPERATING.

a. Clean the test fixture high-voltage test compartment with alcohol to eliminate all grease, oils and debris. Remove the test fixture electrodes and test chamber.

b. Ground the Partial Discharge Detection System, (PDDS) power separation filter high-voltage terminal.

c. Connect the test fixture interlock in series with the PDDS interlocks.

d. Connect the test fixture ground to the PDDS power separation filter ground terminal.

e. Connect the test fixture high-voltage lead to the PDDS power separation filter high-voltage terminal. Adjust the high-voltage lead to exit through the center of the test fixture rear opening.

f. Close the test fixture doors. Check operation of interlock system.

g. Do not remove the PDDS power separation filter ground until the system is ready for checkout.

5.3.3 Checkout. Remove the PDDS power separation filter ground. Slowly increase the voltage in 10 kv steps to 60 kv. Monitor the PDDS output detector and MCS and record any partial discharges at each step. Slowly decrease the voltage to zero. Open the test fixture doors. Ground the PDDS power separation filter high-voltage terminals.

5.3.4 Operation.

a. Install the test chamber in the test compartment, insert the banana plugs into the high-voltage and low-voltage terminals in the base of the test compartment.

b. Install the test fixture in the test chamber, and insert the banana plug on the base of the test fixture into the high-voltage terminal in the test chamber. Insert the banana plug attached to the upper electrode lead into the ground terminal banana plug in the base of the test chamber.

c. Insert the test specimen into the fixture.

d. Fill the test chamber with liquid until the liquid covers the top side of the upper test fixture electrode.

e. For test specimens not requiring oil, the test fixture may be installed in the test compartment without the test chamber. Connect the two terminals as though the test chamber were used.

f. Remove the ground from the PDDS power separation filter.

g. Close the test fixture doors. The insulation system is ready to test.

h. Starting at the low kv range on the PDDS, adjust the high-voltage output as specified in the PDDS test procedure.

i. At the conclusion of each test, the PDDS voltage shall be reduced to zero, the PDDS power separation filter high-voltage terminal grounded, and the test fixture interlocked doors opened.

j. Remove the test specimen and prepare for the next test.

5.4 Partial Discharge Verification Tests. Partial discharge tests were performed to verify the high-voltage merit of the test fixture, the partial discharge test facility, and the test article.

5.4.1 Test Requirements. The following requirements apply:

a. Atmospheric pressure: 100 $\pm$ 20 kilopascals.

b. Temperature: $25^{\circ} \pm 5^{\circ}$ C.

c. Relative humidity: 50% to 90%.

d. Corona free test voltage. The test voltage shall be 0 to 30 kV dc or 10 kV rms at 60 Hz or 400 Hz.

e. Rate of application - the test voltage shall be raised uniformly from zero to 50 percent of test specimen rated voltage in not less than 5 seconds; from 50 percent to maximum rated voltage the rate of rise shall not exceed 500 volts per second.

5.4.2 Test Specimen. The test specimens used in the verification test program are described in this paragraph. Three, round, brass, flat-surfaced electrode pairs with rounded edges, listed in Table 5.2-1, were used in the test. Each electrode pair was encapsulated in a clear silastic, RTV 615. The RTV 615 was not outgassed so that bubbles would appear during the curing process. A photograph of the electrode pair is shown in Figure 5.4-1. Electrode spacing between the electrode pair is shown in Table 5.4-1.

TABLE 5.4-1: ELECTRODE SPACING

Electrode Diameter		Electrode Spacing	
1 inch	Cm	1 inch	Cm
2	5.08	0.2	0.508
1	2.54	0.15	0.381
0.25	0.635	0.05	0.127

5.4.3 Tests. Partial discharge tests were made at 60 Hz and 400 Hz. The test articles were cleaned with alcohol to remove grease and debris accumulation, and then installed in the test fixture. The test procedure listed in paragraph 5.4.1 was followed.

5.4.4 Test Results. The pertinent test results are shown in Table 5.4-2. Each electrode pair was tested for inception voltage (CIV) extinction voltage (CEV), and for partial discharges within the voids between and on the surfaces of the electrodes. The number partial discharges at the picrocoulomb levels indicated in Table 5.4-2 were taken at the initiation voltage for one minute acquisition time. The test articles were not subjected to

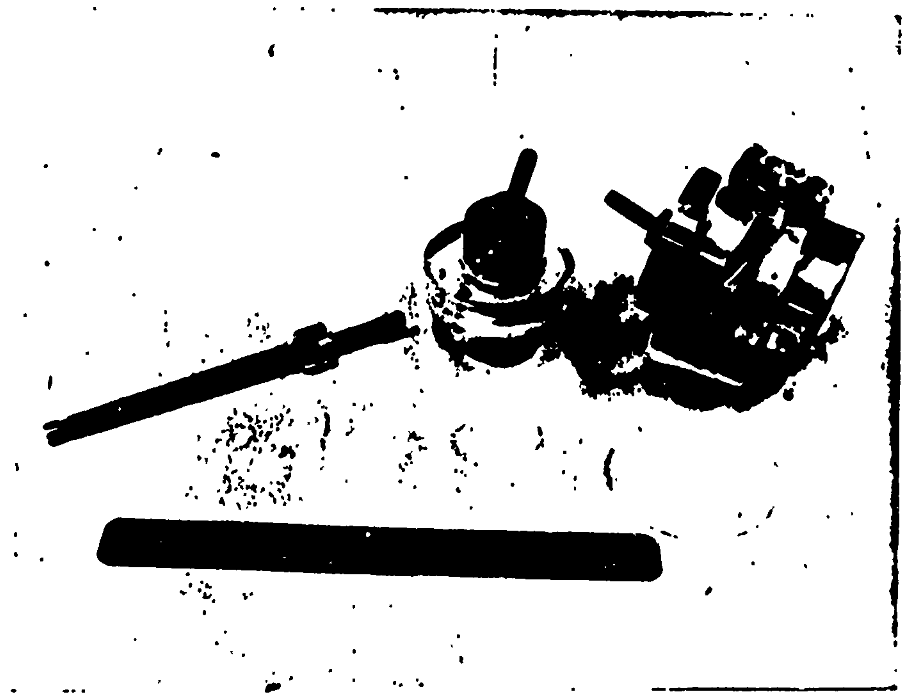


Figure 5.4-1: Electrode Pairs Encapsulated in RTV615

TABLE 5.4-2: STANDARD TEST FIXTURE TEST DATA

STANDARD TEST FIXTURE	FREQUENCY Hz	PARTIAL DISCHARGES CIV kVrms	PARTIAL DISCHARGES CEV kVrms	TEST VOLTAGE kVrms		PARTIAL DISCHARGES HIGHEST PC	PARTIAL DISCHARGES COUNTS AT PC		PARTIAL DISCHARGES COUNTS OVER PC	
2.0 inch diameter electrodes	60	8.5	7.7	8.63	CTS 15	80	16	30	694	30
	← after 2 minutes with voltage on									
	60			8.63	"	4050		2000	675	2000
	60	6.44	5.15	7.07		2800	1	2000	3	2000
	400	6.44	5.65	7.07		8100	6	5000	201	5000
1.0 inch diameter electrodes	60	4.8	4.17	4.87		220	75 at	150	4199	150
	400	5.45	4.38	4.81		175	35 at	150	120	150
0.25 inch diameter electrodes	60	2.54	1.62	2.4		8300	4 at	4000	313	4000
	400	2.19	1.91	2.4		7350	10 at	4000	89	4000
				2.4 + 1 minute		5500	3 at	4000	88	4000

a dielectric withstanding voltage to eliminate the probability of damage to the dielectrics.

5.4.5 Analysis. The test data shown in Figure 5.4-2 and Table 5.4-2 indicate that the extinction voltage is slightly higher for 400 Hz than for 60 Hz. This can be caused by several factors: the time the partial discharges are allowed to occur between inception and extinction, the size of the voids and the magnitude of the inception voltage, and instrumentation error. The 60 Hz and 400 Hz values will move closer together with added testing until there will be little difference in the two values.

Another notable result is the very low picocoulamb (PC) values for the one-inch diamaeter electrode pair. This was due to the smaller and fewer voids in the material, that is, the larger the void, the higher the voltage required to discharge across the void and the greater the capacitance of the void.

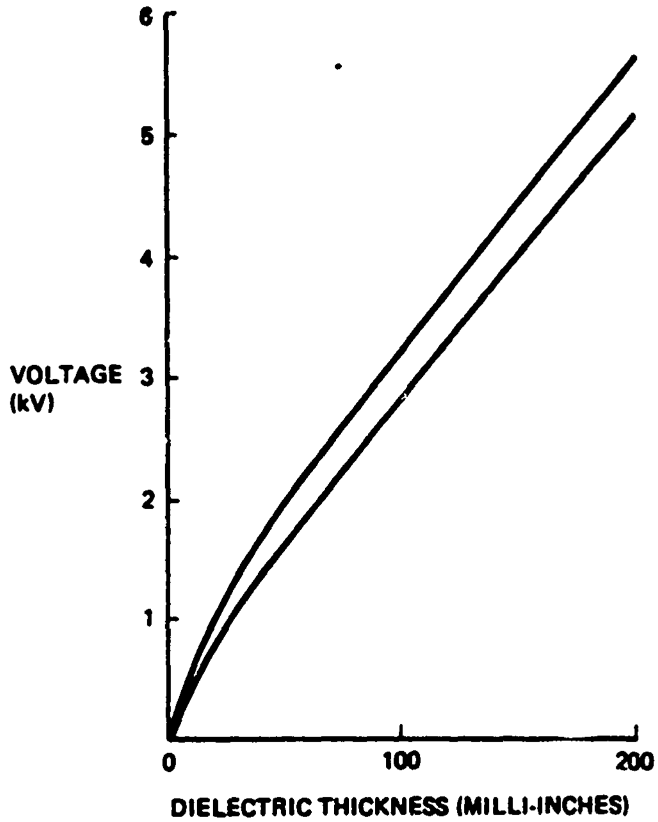


Figure 5.4-2: Partial Discharge Extinction Voltage as a Function of Dielectric Thickness and Frequency

6.0 TEST ARTICLES

6.1 Introduction. Engineering criteria documents were developed for eight components for high-power, high-voltage airborne systems on contract F33615-77- C-2054, "High Voltage Specifications and Tests (Airborne Equipment)" in 1977 and 1978. The eight criteria documents were written in accordance with military specifications for: cables, cable assemblies, capacitors, connectors, converters, power sources, and transformers and inductors.

Included in each criteria document were high-voltage tests and test parameters based on insulation design parameters and engineering judgment. In this program eight test articles were selected which represented components or component parts for the components discussed in the criteria documents. The selected test articles are:

- Cable
- Cable Assembly
- Connector
- Alternator Coil (Section)
- Transformer Coil
- Capacitors

Each test article was tested for one or more of the following:

- Insulation Resistance
- Dielectric Withstanding Voltage
- Pulse Voltage
- Partial Discharges (Corona)

In most cases, the test article was tested for capacitance to determine the loading for the partial discharge test facility. Section 6.2 of the document is devoted to the description of the test articles. Section 6.3 is devoted to the test plan, including the test parameters. The test data is in Section 6.4 and a correlation of the test results and parameters set forth for similar test articles in the criteria documents, and changes to the criteria document test procedures and parameters.

6.2 Test Articles. The eight test articles were either purchased from or supplied by manufacturers of high-voltage, high-power components for high-voltage, high-power equipment.

6.2.1 Cables, Cable Assembly and Connector. One connector assembly and one cable assembly were purchased from Contractor A. The cables were constructed with a semicon layer extruded over the inner conductor, the primary insulation extruded over the inner semicon layer and an outer semicon layer, extruded over the primary insulation next to the shield as described in the cable criteria document, AFAPL-TR-79-20R4, "High Voltage Specifications and Tests". The connector and shield termination was molded onto the cable as described for the connector in the connector criteria document. The primary insulation was EPR, the semicon layers carbon-filled EPR, and the outer jacket neoprene. The 90kV cable assembly is designed to be tested as a cable when the connector mating half is disconnected. Test configurations are described in Table 6.2-1. A photograph of the 90kV (A-1 and A-2) cable assemblies with connector unmated is shown in Figure 6.2-1. The unmated cable assembly A-2 and Connector A-3 are shown in Figure 6.2-2. A two-connector cable assembly of the same design is designated A-4. Other cable assemblies that were subjected to partial discharges are shown in Figures 6.2-3 and 6.2-4. Two special cables (Figure 6.2-3), rated 17 Kv dc, were supplied by manufacturer A for test and evaluation at high-voltage. The connector on the right hand side of the photograph is not bonded to the cable shield. This design made it possible to obtain data for the cable A-5, connector A-6, the cable assembly A-7.

A 75 Kv dc modulator cable is shown in Figure 6.2-4. A (used) mating connector was also available for test (Figure 6.2-5). The cable is used in an operational system and has an accumulation of more than 2×10^9 impulses. The purpose of this test was to determine damage and/or life degradation to the cable assembly by use. The new cable assembly is designated A-8, the old cable assembly A-9, and the connector A-10.

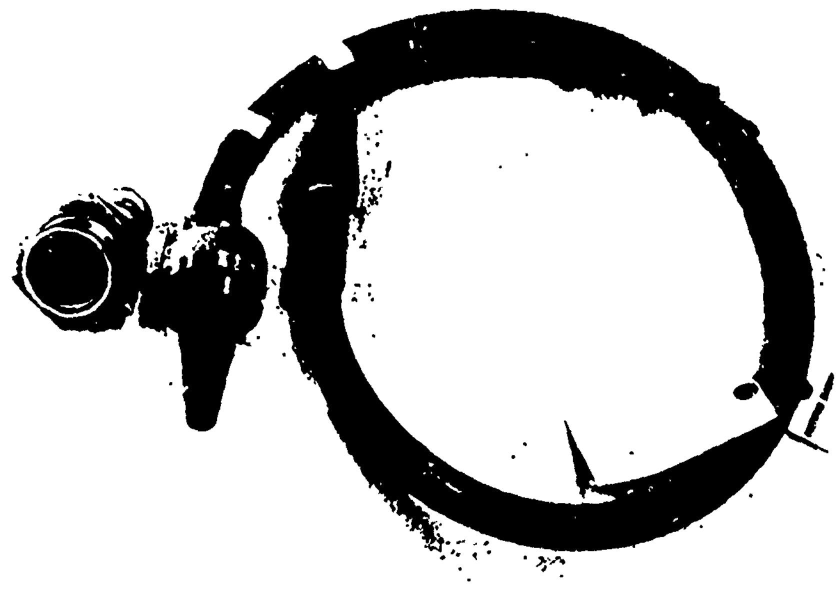


Figure 6.2-1: Cable Assembly and Connector

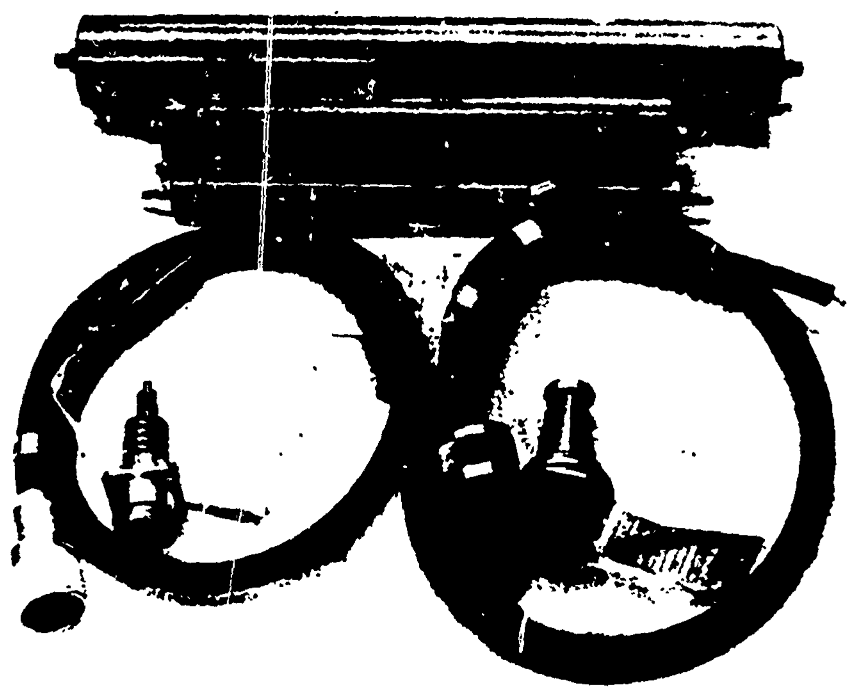


Figure 6.2-2: Test Articles

Figure 6.2-3: Special Cable Assembly, Rated 17 kVdc

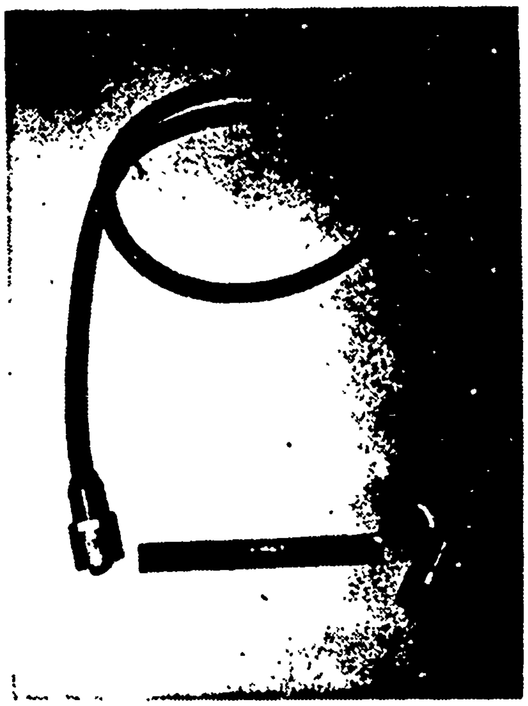
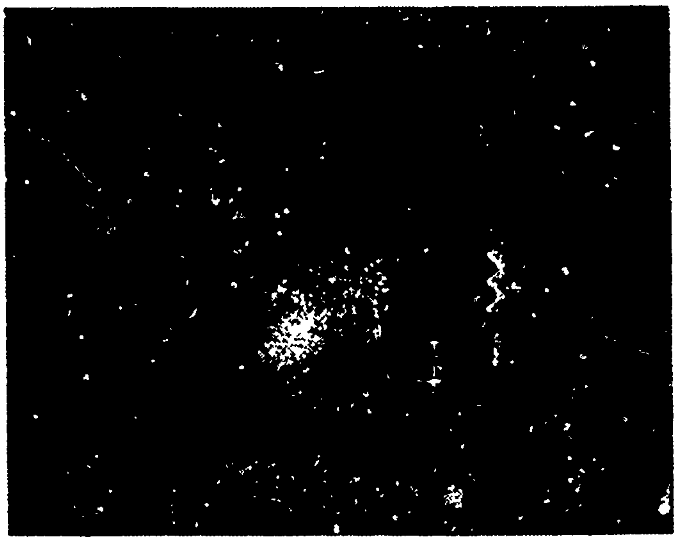


Figure 6.2-4: Modulator Cable Assembly, Rated 75 kVdc



Left side specimen:
Modulator cable
Connector, 1-10
Rated 75 kVdc in SF_6

Right side specimen:
Connector
A-3 Rated 60 kVdc in air

Figure 6.2-5: Connectors

TABLE 6.2-1: CABLE ASSEMBLY TEST CONFIGURATION

Configuration	Part Designation	Test Article	Voltage Rating K Vdc
Cable	A-1	Cable Only	90
Cable Assembly	A-2	Cable and Connector	90
Connector	A-3	Connector with High Voltage Lead	60
Cable Assembly	A-4	Cable with two Connectors	60
Cable	A-5	Cable Only	17
Connector	A-6	Connector Only	17
Cable Assembly	A-7	Cable with One Connector	17
Cable Assembly	A-8	New Modulator Cable	75
Cable Assembly	A-9	Used Modulator Cable	75
Connector	A-10	Modulator Cable Connector	75

6.2.2 Capacitors. Three, cylindrical, plastic-cased, high-voltage capacitors were purchased from Contractor B and one rectangular metal-cased capacitor was supplied by the U.S. Air Force from Contractor C. The electrical and physical parameters of the capacitors from Contractor B are listed in Tables 6.2-2 and 6.2-3. A photograph of the capacitors is shown in Figure 6.2-6.

Table 6.2-2: Electrical Parameters Of Capacitors

Unit	Contractor	Part Designation	Capacitance, Microfarads	Voltage Rating, kV	Use
1	B	B-1	0.005	100	Filters with low-inductance and high-peak current capacity.
2	B	B-2	0.005	100	Low inductance and dissipation factor for high current, high rep-rate, fast pulse discharge operation.
3	B	B-3	0.001	80	Low inductance, high peak operation up to 10^5 shots with rep-rates to 100 PPS.
4	C	C-1	2.2	15	High energy density for use in PFN with repitition rates to 300 PPS.

Table 6.2-3: Physical Characteristics Of Capacitors

Unit	Part Designation	Length Inches	Width Inches	Diameter Inches	Height Inches	Configuration	Case	Terminals
1	B-1	17½	-	2¼	-	Round	Phenolic	2
2	B-2	25	-	3¼	-	Round	Phenolic	2
3	B-3	13½	-	1	-	Round	Phenolic	2
4	C-1	6	4	-	6	Rectangular	Metal	2

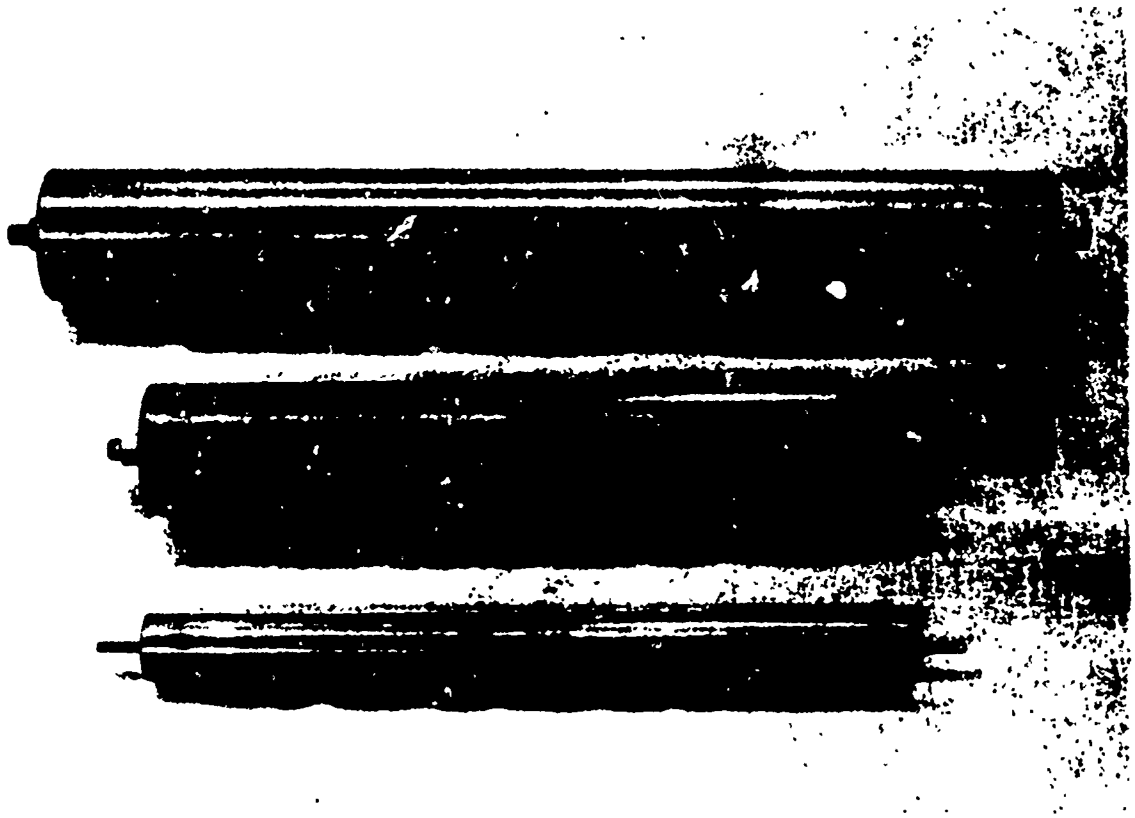


Figure 6.2-6: Capacitors

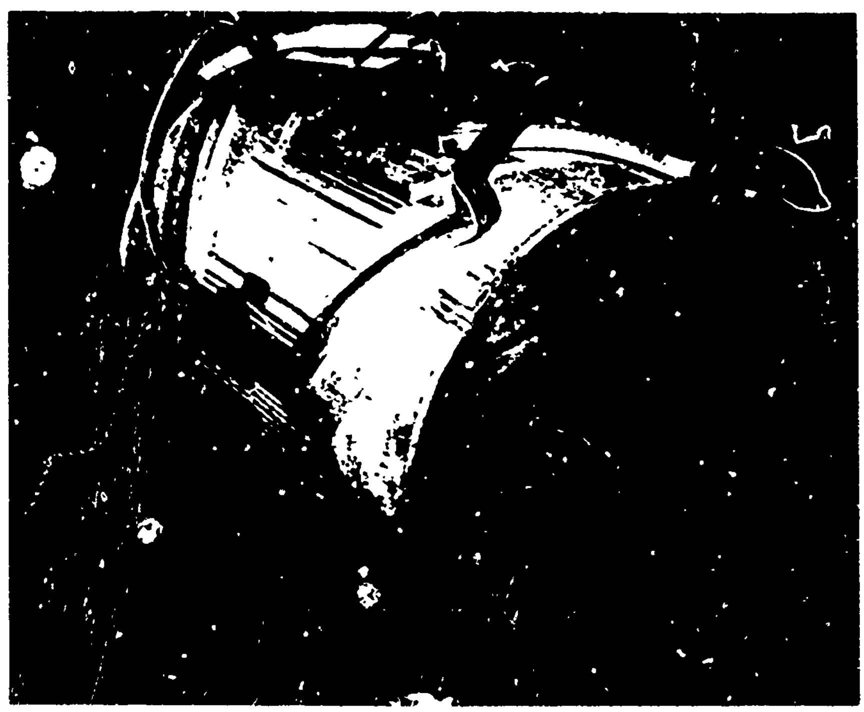


Figure 6.2-7: Two Coils Mounted on a 34 Inch Wooden Jig as in an Alternator Stator

6.2.3 Alternator Coil. Three straight sections of an alternator coil and a test jig with two full sized alternator coils were obtained from Contractor D for test. One coil was mounted on the jig in phase A position, the other coil in phase B position as shown in Figure 6.2-7. Each straight section and coil is insulated as in the final alternator configuration consisting of six square tubular copper coils sections as shown in Figure 6.2-8, without the 0.039 to 0.056 inch taper insulation. The conductor insulation is double glass, nominal 10-mil build. The coil is half-lap wrapped, nominal 6-mil Fusa-Fab^R polyester and glass tape. The wedge adjacent to the coil in Figure 6.2-8 is not part of the coil. Wedges are cut to fit the actual gaps between coils; the wedge will be simulated by placing strips of 6-mil Fusa-Fab^R polyester between adjacent coils during test. The rated voltages for the generator are:

- coil-to-coil 2.8 kV
- phase-to-phase 29.6 kV

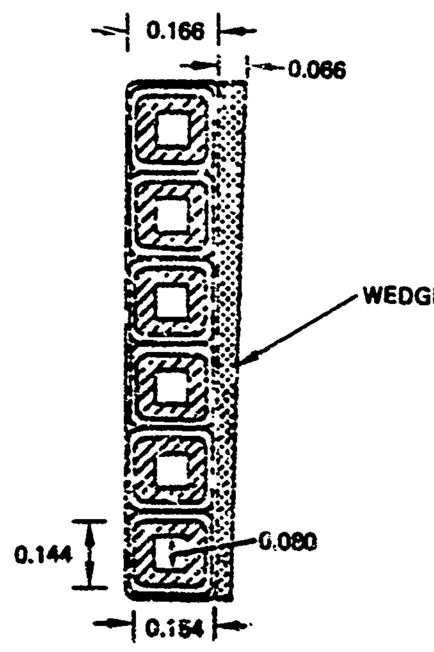


Figure 6.2-8: Coil Cross Section

6.2.4 Pulse and Power Transformers. Two two-winding pulse transformer and one two-winding power transformer coil were obtained from contractor E for test. The insulation system in all three transformers is transformer-oil impregnated Nomex film. A photograph of the power transformer E-1 windings is shown in Figure 6.2-9. The electrical stress across the insulation system is 125 to 350 volts/mil, well within the recommended rating for the materials. A list of the transformers tested is shown in Table 6.2-4.

TABLE 6.2-4: PULSE TRANSFORMERS

Configuration	Part Designation	Primary Voltage Kv Peak	Secondary Rating Kv Peak
Power Transformer Coil	E-1	0.23*	0.004
Pulse Transformer Coil	E-2	20	200
Pulse Transformer Coil	E-3	20	200
Pulse Transformer	E-4	-	-
Pulse Transformer	E-5	-	-

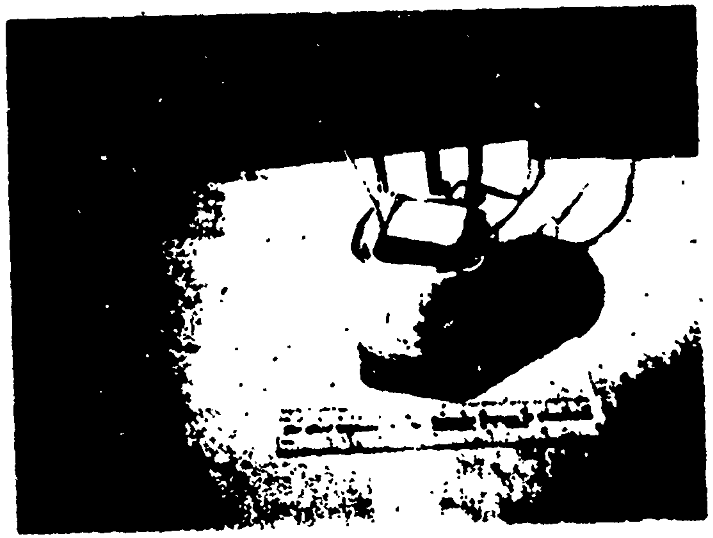
*(20 kV Insulation Primary to Secondary)

Two other pulse transformers E-4 and E-5, were tested. Their rated voltages were unknown. Photographs of these transformers are shown in Figure 6.2-10 and 6.2-11.

6.3 Test Procedure. Each test article was tested in accordance with the test procedures outlined in the High Voltage Criteria documents using test equipment delineated in either the appropriate Military Standards, Military Specifications, ASTM Standards, or the High Voltage Criteria Document. The specific test procedure and test equipment are detailed for each test.

6.3.1 Insulation Resistance. When tested for insulation resistance at a potential of 500 ± 50 Vdc, the minimum insulation resistance shall be greater than 1000 megohms.

6.3.1.1 Procedure. Each component identified in paragraph 6.2, in turn, shall be attached to an electrical circuit and a potential of 500 ± 50 Vdc shall be applied between the high



Transformer coil
mock-up

Figure 6.2-9: *Transformer Coil , E-1, Before Test*

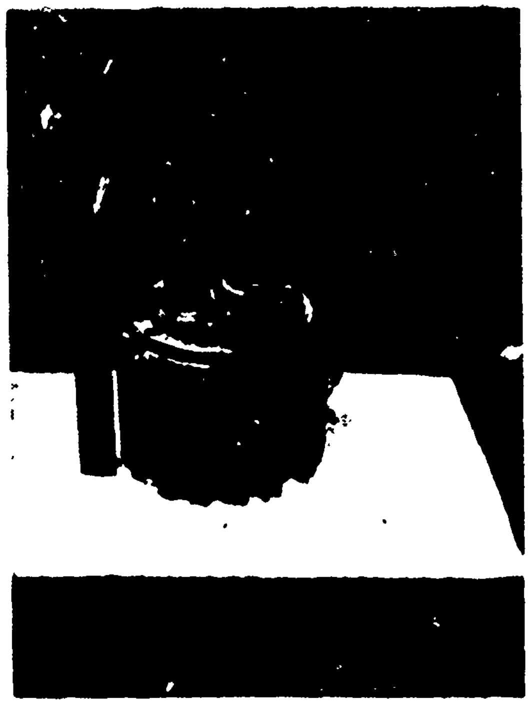


Figure 6.2-10: Pulse Transformer E-4

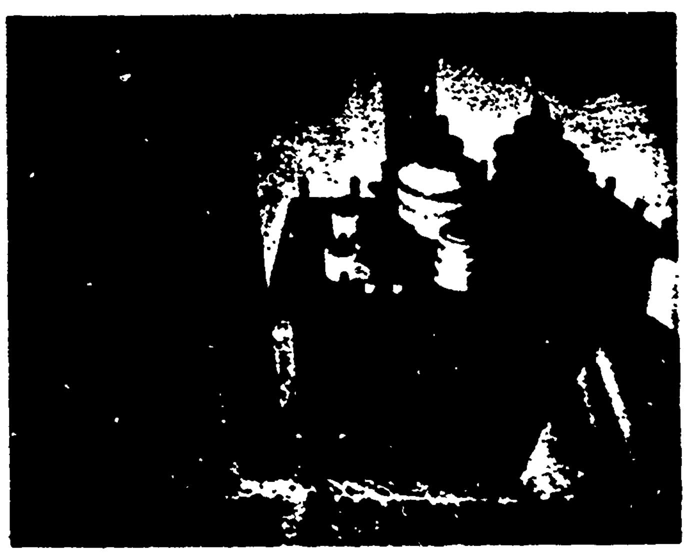


Figure 6.2-11: Pulse Transformer E-5

voltage terminal and ground, or to the generator coils between adjacent coil groups. The potential shall be applied for a period of one minute, minimum. However, if a stable reading is obtained in less than one minute and the results are in excess of 1000 megohms, the minimum allowable, the test may be terminated.

During the energization period, the insulation resistance shall be measured and shall be 1000 megohms, minimum.

6.3.1.2 Connections. Electrical connections shall be made to the test article terminals as described in Table 6.3-1.

TABLE 6.3-1: ELECTRICAL CONNECTIONS

TEST ARTICLE		CONNECTIONS	
CONFIGURATION	PART DESIGNATION	POSTIVE	NEGATIVE
Cable	A-1	Center Conductor	Shield
Cable Assembly	A-2	Center Conductor	Shield
Connector	A-3	Center Conductor	Shield
Cable Assembly	A-4	Center Conductor	Shield
Capacitor	B-1	(+)Terminal	(-)Terminal
Capacitor	B-2	(+)Terminal	(-)Terminal
Capacitor	B-3	(+)Terminal	(-)Terminal
Capacitor	C-1	(+)Terminal	(-)Terminal
Alternator Coil Section	D-1	Conductor #1	Conductor #2
Alternate Coils	D-2	Phase A	Phase B
Transformer Coil	E-1	Primary	Secondary

6.3.1.3 Instruments. Insulation resistance shall be measured with certified calibrated instruments. Approved instruments or equivalent are listed in Table 6.3-2.

TABLE 6.3-2: INSTRUMENT FOR MEASURING INSULATION RESISTANCE

Instrument Function	Manufacturer	Model
Insulation Resistivity	General Radio	GR 1862C

6.3.2 Capacitance. When test articles are tested for capacitance, the capacitance shall be within ± 1.0% of the specified value.

6.3.2.1 Procedure. Each component identified in Paragraph 6.2, in turn, shall be attached to an electrical circuit and tested for capacitance as specified in MIL-STD-202, Method 305. A frequency of 100 Hz shall be applied between the active terminals or parts.

6.3.2.2 Connections. Electrical connections shall be made to the applicable test articles' terminals as described in Table 6.3-1.

6.3.2.3 Instruments. Capacitance shall be measured with the certified calibrated instrument or equivalent, as shown in Table 6.3-3.

TABLE 6.3-3: CAPACITANCE MEASURING INSTRUMENT

Instrument	Manufacturer	Model
Capacitance Bridge	ESI	ESI 270

6.3.3 Dissipation Factor. The three capacitors listed in Table 6.2-2 shall be tested for dissipation factor. The dissipation factor shall be less than 0.050 ± 2 percent instrumentation error.

6.3.3.1 Procedure. A component identified in Table 6.2-2 to be tested for capacitance shall be connected to an electrical circuit and tested for dissipation factor per AFAPL-TR-79-2024, (Appendix C, Paragraph 6.7.11). A frequency of 100 ± 10 Hz at a voltage not to exceed 20 percent of the capacitor rated voltage shall be applied between the active terminals listed in Table 6.3-1.

6.3.3.2 Connections. Connections shall be made to the capacitor terminals as described in Table 6.3-1.

6.3.3.3 Instruments. The dissipation factor shall be measured with the certified calibrated instruments or equivalent, as shown in Table 6.3-4.

Table 6.3-4: DISSIPATION FACTOR MEASURING INSTRUMENT

Instruments	Manufacturer	Model
Capacitance Bridge	ESI	ESI-270

6.3.4 Dielectric Absorption. The three capacitors, B-1, B-2, and B-3, listed in Table 6.2-2, shall be tested for dielectric absorption. The dielectric absorption time shall be within 15 minutes.

6.3.4.1 Procedure. Each component identified in Table 6.2-2, in turn shall be attached to the electrical circuit of Figure 6.3-1.

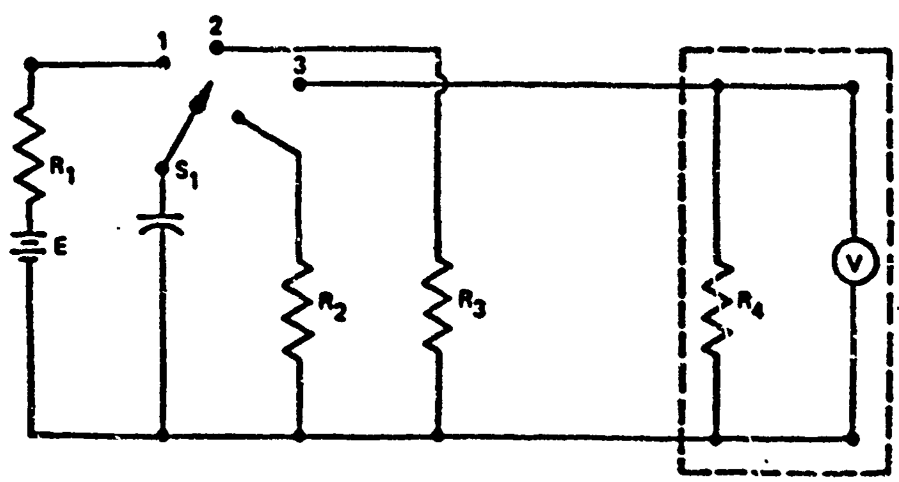


Figure 6.3-1: Typical Production Dielectric Absorption Test Circuit

The capacitor shall be charged at 50 percent of the dc voltage rating for 2 hours $\pm$ 1 minute. The initial surge current shall not exceed 50 milliamperes. At the end of this period, the capacitor shall be disconnected from the power source and discharged through a 5 ohm $\pm$ 2 percent resistor for 10 $\pm$ 1 seconds. The discharge resistor shall be disconnected from the capacitor and the recovery voltage shall be measured with an electrometer or other suitable device having an input resistance of 10,000 megohms, or greater. Recovery voltage shall be read at the maximum voltage within a 15 minute period. The dielectric absorption shall be computed from the following formula:

$$d = \frac{V_1}{V_2} \times 100$$

Where:

d	=	Percent dielectric absorption
V_1	=	Maximum recovery voltage
V_2	=	Charging voltage

6.3.4.2 Capacitor Connections. Connections shall be made to the capacitor terminals as described in Table 6.3-1.

6.3.4.3 Instruments. Dielectric absorption shall be measured using the certified calibrated instruments, or equivalent, listed in Table 6.3-5.

TABLE 6.3-5: DIELECTRIC ABSORPTION MEASURING INSTRUMENTS

Instrument	Manufacturer	Model
Power Supply	TRYGON	M160-5A
Electrometer	Keithly	610BR
Timer	Graylab	167

6.3.5 Dielectric Withstanding Voltage (DWV). The test articles listed in Table 6.3-6 shall be tested for DWV. When tested to the specified test parameter for one minute, there shall be no evidence of breakdown, arcing, or other visible damage to the test article.

TABLE 6.3-6: DIELECTRIC WITHSTANDING VOLTAGE PARAMETERS

Test Article	Part Designation	Rated Voltage kV	Test Freq.	Test Voltage kV #1	#2	#3
Cable	A-1	90	DC	108	125	144
Cable Assembly	A-2	90	DC	108	125	144
Connector	A-3	60	DC	72	86	100
Cable Assembly	A-4	60	DC	Not Tested	-	-
Capacitor	B-1	100	DC	160	180	200
Capacitor	B-2	100	DC	[illegible]	180	200
Capacitor	B-3	80	DC	130	145	160
Alternator Coil Sections	D-1	2.8	60Hz	2.8	3.2	3.6
Alternator Coils	D-2	29.6	60Hz	35.5	41.5	47.4
Power Transformer	E-1	20	60Hz	20	28	45
Pulse Transformer	E-3	10	60Hz	16	-	-

6.3.5.1 Procedure. Each test article listed in Paragraph 6.2, in turn, shall be connected to a high-voltage electrical circuit per MIL-STD-202, Method 301. The component shall be tested in accordance with MIL-STD-202, Method 301, with the test parameters listed in Table 6.3-6. The duration of the test shall be one minute ± 5 seconds. Leakage current shall be measured and plotted for each coil insulation configuration. Coils shall be tested with 1, 2, and 3 strips of insulation between coils. Connections shall be as shown in Table 6.3-1.

6.3.5.2 Instruments. DWV shall be measured using the certified calibrated instrument, or equivalent, listed in Table 6.3-7.

TABLE 6.3-7: DIELECTRIC WITHSTANDING VOLTAGE INSTRUMENT

Instrument	Manufacturer	Model
250Kv Power Supply	Universal Voltronics	BAL200-18

6.3.6 Pulse Test. Each component listed in Table 6.3-8 shall be subjected to pulse tests separated a minimum of 20 seconds apart. Testing shall be discontinued if there is evidence of breakdown, arcing, or other physical damage to the test articles.

6.3.6.1 Procedure. Each test article listed in Table 6.3-8, in turn, shall be connected to an electrical circuit as specified in IEEE Publication, Number 4, 1978, ANSI C-57, or ANSI C-93. Test points shall be as shown in Table 6.3-1. The pulse voltage levels shall be as shown in Table 6.3-8. The pulse voltage profile shall be as specified in the above mentioned IEEE Publication Standard and similar to that shown in Figure 6.3-2, using an instrument such as that described in Table 6.3-9.

TABLE 6.3-8: PULSE VOLTAGE PARAMETERS

Test Article	Part Designation	Peak Voltage Minimum kV	Peak Voltage Maximum kV
Cable	A-1	120	200
Cable Assembly	A-2	120	200
Connector	A-3	80	120
Cable Assembly	A-4	80	120
Capacitor	B-1	120	200
Capacitor	B-2	120	200
Capacitor	B-3	100	160
Capacitor	C-1	10	15
Alternator Coil Section	D-1	4	10
Alternator Coil to Coil	D-2	42	105
Transformer Coil	E-1 Primary	20	40
	Secondary	200	320
	Pri-sec	28	56

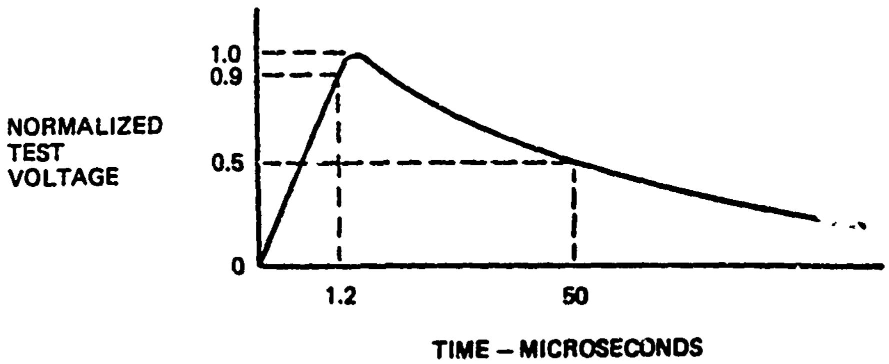


Figure 6.3-2: Basic Insulation Level Test Voltage Profile

TABLE 6.3-9: PULSE TEST INSTRUMENTS

INSTRUMENT	MANUFACTURER	MODEL
Marx Generator	USAF	
2-7 Stages		
0.3 MFD - 0.1 MFD		
35KV - 225kv		
Voltage Divider	Hipotronics	RVD 1000
Power Supply	Hipotronics	8100-25
Storage Oscilloscope	Hewlett-Packard	1744A (100 MHz)

6.3.7 Partial Discharges. The test articles listed in Paragraph 6.2 shall be tested for partial discharges. When tested for partial discharges to the specified test parameters, there shall be no evidence of breakdown, arcing, or other visible damage to the test article.

6.3.7.1 Procedure. Each test article listed in Paragraph 6.2, in turn, shall be connected to the high-voltage circuit of a partial discharge test facility and tested for partial discharges and/or corona. Capacitors shall be tested with dc voltages only. The cable, connector, and cable assembly shall be tested with ac and dc voltages. AC voltages (rms) shall be 35.5% of the dc voltage. Generator and transformer coils shall be tested with ac voltages only. The following details shall apply:

(a) Magnitude of test voltage - 100% component rated voltage;

(b) Nature of potential - dc or ac, as applicable to the test article;

(c) Duration of application of test voltage - partial discharges shall be measured for 60 seconds after the operating voltage is attained. Voltage shall be increased from 0 to operating test voltage at a rate of 500 volts per second. A dead-time of 15 seconds shall elapse between the time rated voltage is attained and partial discharge data is accumulated for dc partial discharge test articles;

(d) Points of application of test voltage - as specified in Paragraph 6.2;

(e) Examination after test - the test article shall show no visible damage;

(f) Partial discharges shall not exceed more than one discharge per minute above 10 pc. Partial discharges greater than 1000 pc are unacceptable. Partial

discharges within the test article shall be calculated per ASTM D1868 or ASTM D3382-75.

6.3.7.2 Instruments. Partial discharges shall be measured using the corona test facility located at the U.S. Air Force Aero Propulsion Laboratory AFWAL/POOS-2, which includes a 17000-3 Partial Discharge Detector, a 150 kV (17187-2) Power Separation Filter, 400 Hz (17189-1) Power Separation Filter manufactured by J. G. Biddle Co.; an ND60 Nuclear Data, Inc., Multichannel Analyzer; and a 150 kV 400 Hz Power Supply manufactured by Hipotronics.

6.4 Test Data. The eight test articles were tested for insulation resistance, capacitance, and dielectric withstanding voltage using the test procedures and equipment delineated in Paragraph 6.3.

6.4.1 Insulation Resistance. The insulation resistance test data is shown in Table 6.4-1. Insulation resistance was measured at 500 volts, dc.

TABLE 6.4-1: INSULATION RESISTANCE

Test Article	Part Designation	Insulation Resistance, Megohms
Cable	A-1, Connector Unmated	2.0×10^6
Cable Assemblies	A-1, Connector Mated	2.0×10^6
Connector	A-2, Connector Mated	2.0×10^6
	A-3, Connector Unmated	2.0×10^6
Capacitors	B-1	1.25×10^5
	B-2	1.0×10^6
	B-3	5.6×10^5
Transformer Coil	E-1	1.0×10^9

Two alternator coil sections were tested in four configurations; 1) in parallel, 2) in parallel with one strip insulation 3) in parallel with two strips insulation; and 4) in parallel

with three strips insulation. The insulation strips are 6-mil Fusa-Fab[R] polyester material. The strips are 0.88 inch wide and 20 inches long. The insulation resistances for four configurations are shown in Table 6.4-2.

TABLE 6.4-2: ALTERNATOR COIL INSULATION RESISTANCE

Configuration Insulation Strips	Insulation Resistance Megohms
0	7×10^5
1	1×10^6
2	2×10^6
3	2×10^6

6.4.2 Capacitance. The capacitance of each test article is shown in Table 6.4-3.

TABLE 6.4-3: CAPACITANCE

Test Article Configuration	Part Designation	Capacitance
Capacitors	B-1	0.00499 mfd
	B-2	0.00484 mfd
	B-3	0.00102 mfd
Cable	A-1 Connector Unmated	173 pfd
Cable Assemblies	A-1	177.5 pfd
Connector	A-2	170.5 pfd
Cable	A-3 Connector Unmated	16[illegible] pfd
Alternator coil sides (parallel with insulation strips)		
	0 strips	320.8 pfd
	1 strip	268.8 pfd
	2 strips	228.8 pfd
	3 strips	203.8 pfd

6.4.3 Dissipation Factor. The dissipation factor for each capacitor is shown in Table 6.4-4.

TABLE 6.4-4: CAPACITOR DISSIPATION FACTOR

Part Designation	Dissipation Factor
B-1	0.0020
B-2	0.0040
B-3	0.0015

6.4.4 Dielectric Absorption. The dielectric absorption was measured by energizing the capacitors to 100 volts dc. The percent dielectric absorption is calculated by the formula:

$$d = \frac{V_1}{V_2} \times 100$$

Where:

d = Percent dielectric absorption

V_1 = Maximum recovery voltage

V_2 = Charging voltage

Test results are shown in Table 6.4-5.

TABLE 6.4-5: DIELECTRIC ABSORPTION

Part Designation	Dissipation Absorption Percent
B-1	2.1%
B-2	2.2%
B-3	2.7%

6.4.5 Dielectric Withstanding Voltage. Each test article was subjected to the dielectric withstanding voltages shown in Table 6.3-6 using the instrument shown in Table 6.3-7. The test results are shown in Table 6.4-6. The laboratory report data is shown in Appendix A.

TABLE 6.4-6: DIELECTRIC WITHSTANDING VOLTAGE TEST DATA

Test Article	Part Designation	Test Voltage Rated kV	Test Voltage Passed kV
Cable	A-1 Connector Unmated	90 dc	144 dc
Cable Assembly	A-2	90 dc	144 dc
Cable	A-3 Connector Unmated	60 dc	100 dc
Connector	A-3	60 dc	100 dc
Cable Assembly	A-7	17 dc	27.2 peak
Capacitor	B-1	100 dc	200 dc
Capacitor	B-2	100 dc	200 dc
Capacitor	B-3	80 dc	160 dc
Pulse Transformer	E-1 (HV to LV Coils)	20 peak	45 peak
Pulse Transformer	E-2	20 peak	22.5 peak
Alternator Coils	D-1 Phase-to-Phase	29.6 rms	24.7 rms
Alternator Coils	D-2		25.4 rms (Arc Over)
	Insulation Layers (between sections)		
	0	2.8 rms	6 rms
	1	2.8 rms	6 rms
	2	2.8 rms	6.4 rms
	3	2.8 rms	6.8 rms

Dielectric withstanding voltage measurements were taken in a step series with 10 seconds hold at each of the lower voltage levels and one minute hold at the highest voltage. All test articles passed the dielectric withstanding voltage test except the alternator coils, as it is specified in the High Voltage Specification Criteria documents. The voltage levels for all items other than the alternator coils are shown on the laboratory data sheet in

Appendix A. The alternator coils were tested at normal atmospheric temperatures and pressure rather than in a pressurized vessel. Thus the arc over at 25.4 Kv.

6.4.6 Pulse Test. Each test article listed in table 6.3-8 was subjected to the pulse test voltages shown in Table 6.3-8 using the equipment shown in Table 6.3-9. The test results are shown in Tables 6.4-7 and 6.4-8.

TABLE 6.4-7: PULSE TEST DATA

TEST ARTICLE	PART DESIGNATION	TEST VOLTAGE KV	STATUS
Cable	A-1	120	Failed
Cable Assembly	A-2	120	Failed
Connector	A-3	75	Failed
		Retest 34, 45	Passed
		60	Failed
Cable Assembly	A-4	34, 50	Pass
		68	Connector Joint Failed
Capacitor	B-1	110	Pass
		165	Failure Borderline
Capacitor	B-2	58, 92, 110	Pass
		155, 210	Damage Indicated
Capacitor	B-3	51	Pass
		48	Fail
Capacitor	C-1	7, 12.6, 14.5	Passed
Pulse Transformer	E-1	Secondary to ground 200	Failed
Pulse Transformer	E-2	Primary to ground 6 to 31	Failed
Pulse Transformer	E-2	Pri to Sec 64	Passed (chopped wave)

TABLE 6.4-8: ALTERNATOR COIL SECTION PULSE TEST DATA

Alternator Coil Sections Insulation Layer	Pulse Test Voltage, kv Pass	Failed
0	-	8
1	8	10
2	11	13
3	13	-

The cable assemblies, cables, and connectors failed to meet the specified surge voltage test requirements due to flaws in the connector insulation system. The damaged connectors on configuration A-3 was removed and the cable submerged in oil and tested. It subsequently failed the pulse test by arcing between the shield and conductor across the two-inch insulated surface.

Four capacitors were pulse tested. Capacitor C-1 passed the 200% pulse test, the other capacitors failed at much lower voltages. Capacitor C-1 was designed for pulse application. The low-voltage breakdown for capacitors B-1 and B-3 indicates overstress during the dielectric withstanding voltage test. Test data for the test articles listed in Table 6.4-7 is attached as appendices B and D.

Two transformer coils were pulse tested. The first coil failed when the first surge was impressed across the secondary winding. The second coil was used for subsequent tests. The coil passed the primary to secondary test but failed the primary winding test. The test data is recorded in Appendix C.

The alternator coil sections were pulse tested with and without insulation strips. A fast pulse was used for this test, having a 500 nanosecond rise to full voltage (negative) and a fall to near 0 voltage in 2.5 microseconds as shown in Figure 6.4-1. The coil sections were short (approximately 20 cm long) low-inductance test articles. These short pulse tests give a higher surge stress to the insulation system. The test data are shown in Table 6.4-8 and Appendix C.

Photographs of a pulse voltage applied to an alternator coil with good insulation integrity and high pulse voltage capability are shown in Figures 6.4-1 and 6.4-2. Breakdown is indicated by loss of the original wave shape, such as an oscillation (Figure 6.4-2).

An alternator coil test jig with two coils mounted on the jig are shown in Figures 6.4-3 and 6.4-4. A side view with the intercoil insulation slabs in place between the upper and lower coils halves is shown in Figure 6.4-3. An end view of the insulation slab is shown in Figure 6.4-4. Kaptan tape was placed over the edges of the insulators to lengthen the tracking surface distance. The two spaced coils represent the two phases of the alternator. The pulse waveform was applied between phases (coil A and coil B).

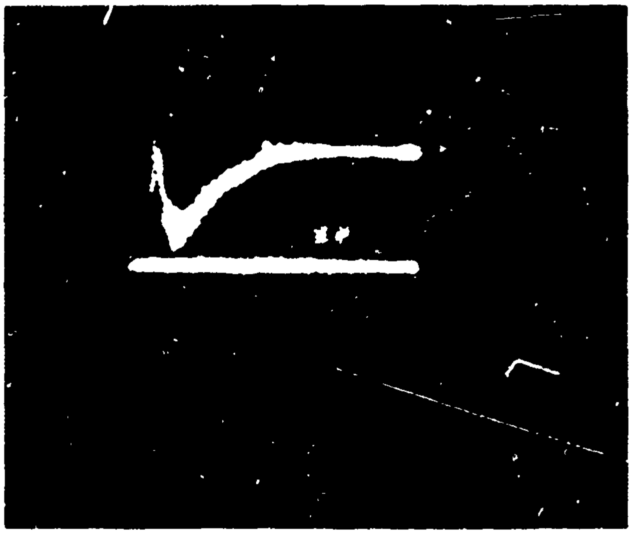


Figure 6.4-1: Generator Coil, D-2 Negative Pulse;
Vertical: 4kV/div, Horizontal: 500μs/div.

Figure 6.4-2: Generator Coil, D-1 Negative Pulse Failure;
Vertical: 2kV/div, Horizontal: 500μs/div.

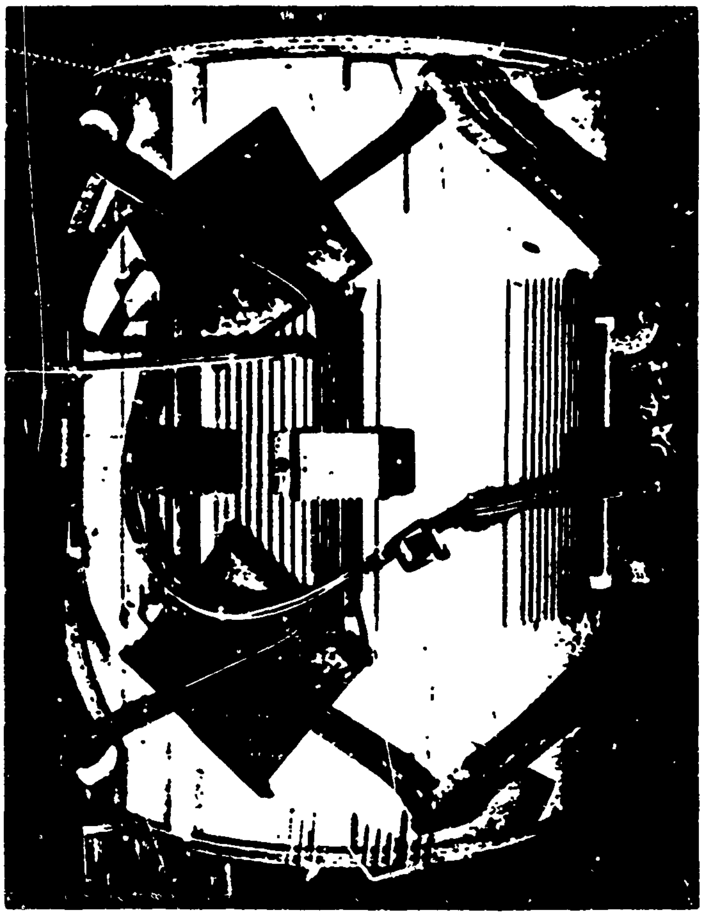


Figure 6.4-3: Insulation Slabs Between Coils

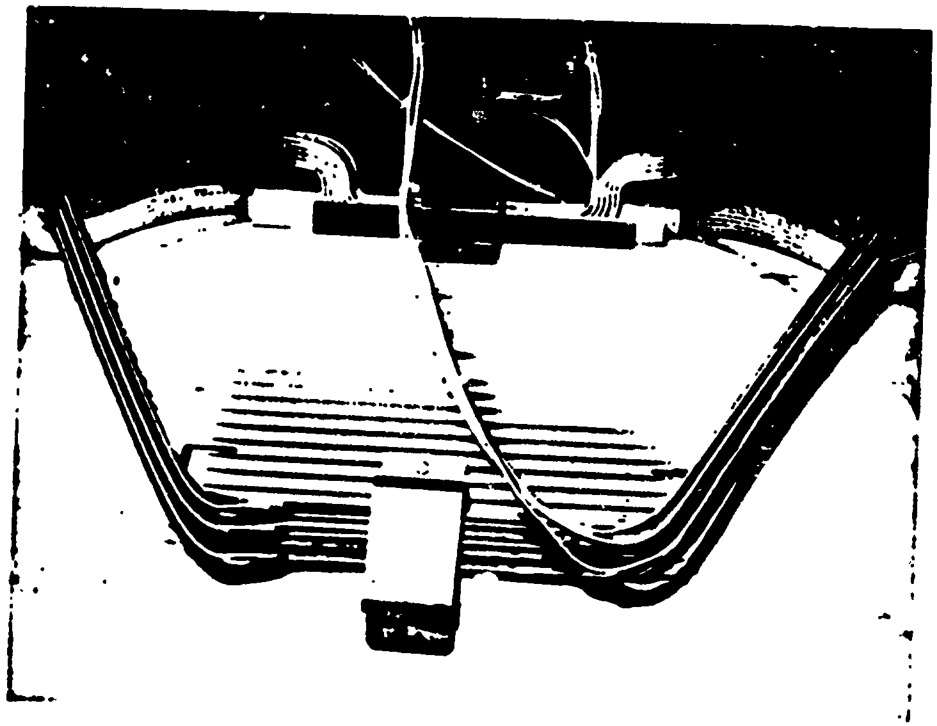


Figure 6.4-4: End View of Slabs Between the Coils

Verification tests were made on the insulation slabs. The slabs, 6" x 6" x 1/2", were placed between a 7/16-inch diameter rod and a 2 1/4 inch diameter Rogowski surface and tested. A photograph of the test fixture electrodes and the test fixture with a slab in place is shown in Figures 6.4-5 and 6.4-6, respectively. The test results for the coil tests and insulator tests are shown in Table 6.4-9.

Table 6.4-9: Alternator Coil and Insulation Pulse Tests

Test Article	Pulse Test Voltage kV	
	Passed	Failed (Flashover)
Alternator Coils		
(Phase-to-phase)		
Air insulation	30	35
Solid insulation	56	61
Insulation (rod gap)		
Specimen #1	65	80
Specimen #2	90	100

The coils successfully passed a 200% surge test but failed the specified 340% specified surge test. The test report is attached as Appendix D.

The cable assembly A-7, was connected such that the cable A-5, connector A-6, or cable assembly could be pulse tested. The test results are shown in Table 6.4-10. To pass the test, the pulse height had to be equal to or greater than 34 Kv peak. The test article in all three configurations passed the test. The connector failed when the test voltage was purposely increased to 300% rated voltage (50 Kv peak).

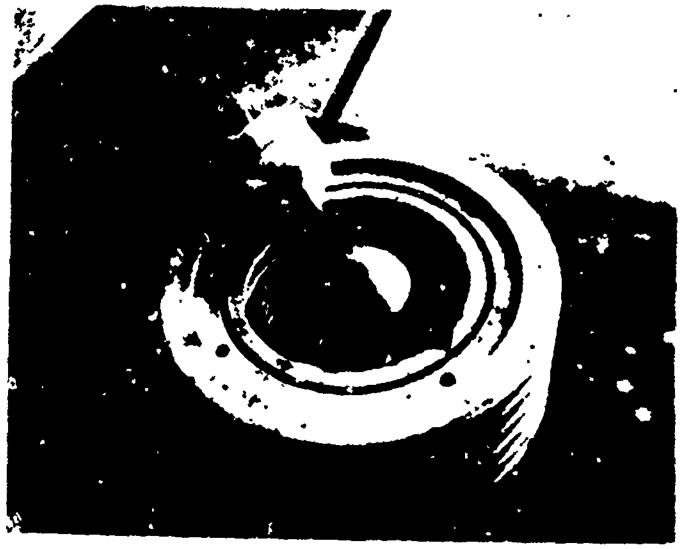


Figure 6.4-5: Test Fixture Electrodes

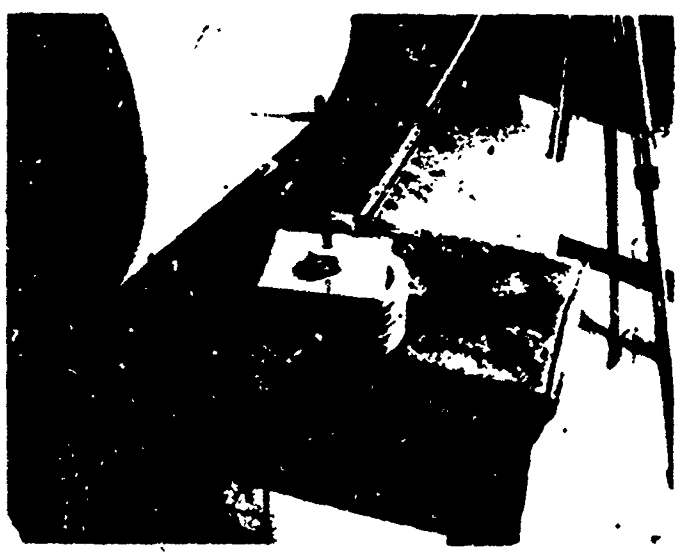


Figure 6.4-6: Test Fixture With Slab in Place Ready for Pulse Test

TABLE 6.4-10: CABLE ASSEMBLY PULSE TEST DATA

Test Article	Part Designation	Test Voltage KV Peak	Test Voltage Status
Cable	A-5	35	Pass
Connector	A-6	35.5	Pass
Cable Assembly	A-7	34.1	Pass
		50.	Connector failed

6.4.7 Partial Discharge Test. Each test article was subjected to either the ac or dc partial discharge tests delineated in Paragraph 6.3.7.1 prior to the pulse test unless otherwise indicated, using the instrumentation specified in Paragraph 6.3.7.2. Test results for the cables, cable assemblies, connectors and capacitors using direct current are shown in Table 6.4-11. The laboratory test data for these items are tabulated in Appendix F. The pulse height count criteria were determined by test at rated dc and ac voltage. For those unrated test articles the counts were determined by test at the partial discharge initiation voltage. The spectral counts collected by the pulse height analyzer are very high in the lower channels (low pc values). The test criteria was that channel which was a crossover from high density counts to low density counts. That is, where the number counts per channel dropped to a value less than 3% of the maximum counts per channel in the lower channels. This crossover point is indicated by the column "counts at PC" in the tables starting with 6.4-11.

TABLE 6.4-11: DC PARTIAL DISCHARGE TEST DATA

Number of partial discharge/second at rated voltage - post pulse test

Test Article	Part Designation	Test Voltage, kV	Pulse Height - PC Highest	Counts at PC		Count over PC	
Cable	A-1	75.3	40	5	20	43	20
Cable Assembly	A-2	Connector Breakdown					
Connector	A-3	60.3	4	15	3	0	4
Cable Assembly	A-4	50.3	5	40	4	0	4
Capacitor	B-1	100.1	40	2	20	22	20
Capacitor	B-2	99.7	4	5	4	0	4
Capacitor	B-3	Breakdown Occurred at 2.5 kV					
Capacitor	C-1						
Prepulse		15	1	0	1	0	1
Postpulse		15	2	1	2	0	2

The alternator coils strip were tested with three 6-mil Fusa-Fab® polyester strips between the insulated conductors. Each conductor is wrapped with nominal 10-mil build glass epoxy. The ac initiation and extinction voltages are tabulated in Table 6.4-12. In addition, the counts/minute at the specific partial discharge magnitude and pulse height analyzer channels are recorded in Table 6.4-13.

TABLE 6.4-12: GENERATOR COIL INITIATION/EXTINCTION VOLTAGES

Test	Insulation* Thickness, mils	Initiation Voltage, kV	Extinction Voltage, kV
1	38	2.9	2.6
2	38	2.9	2.7
3	38	2.85	2.75

*Between conductors

TABLE 6.4-13: GENERATOR COIL PARTIAL DISCHARGE COUNTS/MINUTE AT 2.9kV USING THE PULSE HEIGHT ANALYZER

Picocoulombs, PC	Analyzer Channel	Counts/minute
20	19	87
40	56	92
60	94	78
80	129	52
100	166	42
200	333	8
350	498	1

The pulse transformer, E-2, was dc partial discharge tested before pulse testing, following the primary to secondary winding pulse test, and after the primary winding pulse test. The test results are recorded in Table 6.4-14.

Table 6.4-14 Pulse Transformer, E-2, dc Partial Discharge Test Data

Test Voltage kV	Pulse Height - PC Highest	Counts at PC		Counts over PC	
		Before Surge Testing			
20	0.6	0	0	0	1
28	12	75	5	81	5
45	20	10	10	43	10
		Post Primary-to-Secondary Surge Test			
20	1	1	1	0	1
28	20	5	10	21	10
		Post Primary Winding Surge Test			
20	12	3	10	7	10
28	15	1	10	4	10
45	20	1	20	0	20

Partial discharge data were taken at 60 Hz and 400 Hz for the cables, connectors, and cable assemblies listed in Table 6.4-15. These data were taken at voltages exceeding the partial discharge inception voltage level in most cases. In all cases the highest picocoulomb readings exceeded the specified limits in the criteria documents. When the data was taken at a value less than the extinction voltage (CEV) the highest PC's were within the specified limits (See part A-2, Table 6.4-15).

The ac and dc partial discharge data are compared for cable assemblies in Table 6.4-16. The higher inception voltage and the non-varying voltage greatly decreased the pulse height and counts for the dc voltages.

Partial discharge data were taken for three pulse transformers using ac voltage. The test data is shown in Table 6.4-17.

6.5 Discussion of Test Results. Test data are discussd and analyzed in the following paragraphs. The High Voltage Criteria Documents listed as Appendices in AFAPL-TR-

TABLE 6.4-15: CABLE ASSEMBLY AC PARTIAL DISCHARGE TEST DATA

TEST ARTICLE	PART DESIGNATION	RATED VOLTAGE kVDC	RATED VOLTAGE kVAC	FREQUENCY Hz	CIV kVrms	CEV kVrms	TEST VOLTAGE kVrms	PULSE HEIGHT - PC HIGHEST	PULSE HEIGHT - PC COUNTS AT PC	COUNTS OVER PC	
Cable	A-2	60	21.2	400	10.6	10.1	10.1	86	0 @ 10	4	10
Cable	A-5	17	6	400	-	4.1	4.7	2400	10 at 1000	34	1000
				400	-	-	4.5	1300	9 at 1000	5	1000
				400	-	-	5.0	2150	113 at 1000	581	1000
				60	4.7	4.6	6.5	650	5 at 500	10	500
				60	-	-	6.75	650	82 at 500	174	500
				60	-	-	7.9	900	59 at 500	261	500
				60	-	-	4.0	40	4 at 20	139	20
Connector	A-6	17	6	60	11.6	10.2					
Cable Assy.	A-7	17	6	60	3.63	3.56	6.0	4000	14 at 2000	554	2000
				60	-	-	7.41	6800	2 at 4000	71	4000
				400	3.75	3.75	6.0	3000	10 at 2000	165	2000
				400	-	-	7.41	7750	2 at 4000	165	2000
		DWV ------------		400	-	-	9.6	17000	4 at 15000	8	15000
		DWV-------------		60	-	-	9.6	14500	41 at 10000	272	10000
Cable Assy (New)	A-8	75	26.5	400	18	12.4	15.9	37	6 at 20	85	20
				400	-	-	19.5	160	18 at 100	144	100
				400	-	-	21.2	165	122 at 100	1644	100
				60	17.8	11.6	-	-	-	-	
Cable Assy (Used) (2 x 10^9 pulses)	A-9	75	26.5	400	10.8	7.8	9.4	620	12 at 500	214	500
				60	8.4	8.0	9.4	400	3 at 400	0	400
Connector	A-10	75	26.5	400	11.2	10.2	21.2	3000	11 at 2000	164	2000
				60	12.6	10.2	21.2	5750	2 at 4000	109	4000

TABLE 6.4-16: AC & DC PARTIAL DISCHARGE TEST DATA

TEST ARTICLE	PART DESIGNATION	RATED kVDC	VOLTAGE kVrms	FREQUENCY Hz	CIV kVrms	CEV kVrms	TEST VOLTAGE kVrms	PARTIAL DISCHARGES - PC: HIGHEST	COUNTS AT PC	COUNTS OVER PC	
Connector	A-6	21	6	DC	>21	>21	+17	2.0	1 @ 1	2 1	
				DC	-	-	+21	8	1 @ 1	30 1	
Cable Assy.	A-7	21	6	DC	-	-	+21	1.5	1 @ 1	10 1	
Cable Assy.	A-7	21	6	DC	-	-	-17	1.1	1 @ 1	5 1	
				DC	-	-	-21	7	1 @ 1	9 1	
Connector	A-6	21	6	DC	-	-	-17	2.6	1 @ 1	1 1	
				DC	-	-	-21	6	1 @ 1	14 1	
Connector	A-5	21	6	400	-	-	7.41	3600	16 @ 3000	144 3000	
				60	-	-	6.0	3500	0 @ 3000	4 3000	
				60	-	-	6.0	3100	13 @ 2000	215 2000	
				60	-	-	7.41	3400	12 @ 2000	263 2000	
				400	-	-	6.0	3350	6 @ 3000	34 3000	
				400	-	-	7.41		3 @ 5000	27 5000	
Cable Assy	A-7	21	6	60	3.82	3.26	6.0	310	22 @ 200	116 200	w/putty
				60	-	-	7.41	17000	44 @ 10000	368 10000	w/putty
				60	-	-	7.41	23000	14 @ 10000	196 10000	w/o putty
				400	4.03	3.47	6.0	762	2 @ 200	47 200	w/o putty
				400	-	-	7.41	32500	8 @ 20000	88 20000	
				400	-	-	6.0	16000	49 @ 10000	[illegible] 10000	
				400	-	-	6.0	13000	29 @ 10000	116 10000	
				400	2.76	2.33	7.41	32500	1 @ 20000	25 20000	
				60	-	-	6.0	11000	2 @ 10000	5 10000	
				60	2.47	2.37	7.41	25000	46 @ 10000	505 10000	

TABLE 6.4-17: PULSE TRANSFORMER AC PARTIAL DISCHARGE DATA

TEST ARTICLE	PART DESIGNATION		RATED VOLTAGE kVrms	PRI.	WINDING CONNECTIONS SEC#1	SEC#2	Ter.	CASE/CORE	FREQUENCY Hz	CIV kVrms	CEV kVrms	TEST kVrms	PARTIAL DISCHARGES HIGHEST PC	COUNTS AT PC	COUNTS OVER PC
Transformer (Pulse) Winding	E-3	IN-AIR		*HV	HV	-	-	G	60	2.34	2.2				
									400	2.54	2.12				
				*G	HV	-	-	G	400	1.7	1.56				
		IN-OIL		G	HV			G	400	4.8	3.6	9.9	33000	81 at 20000	1028 - 20000
				G	HV			G	60	4.52	3.25	9.9	49000	34 at 40000	363 - 40000
				G	HV			G	60	-	-	15.9	55000	17 at 40000	255 - 40000
				HV	HV			G	60	2.33	2.05				
				HV	HV			G	400	2.83	2.4				
				G	HV			G	60	1.77	1.48				
				G	HV			G	400	1.70	1.42				
Transformer Pulse	E-4			G	HV	HV	-	G	60	2.26	2.12				
				G	HV	HV		G	400	2.9	2.69				
				G	HV	G		G	60	2.83	2.69				
				G	HV	G		G	400	3.46	2.83				
Transformer Pulse	E-5		30	HV	G	-	G	G	60	3.46	3.18		810	11 at 600	102 - 600
				HV	G	-	G	G	400	3.4	3.11		830	27 at 600	440 - 600
				HV	G	-	F	F	60	4.25	3.82		795	30 at 300	530 - 300
				HV	G	-	F	F	400	4.1	3.82		416	9 at 300	186 - 300
				*F	HV	-	G	F	60	3.02	3.4				
				F	HV	-	G	F	400	2.4	3.18				

HV = High Voltage G = Ground F = Float

2024, "High Voltage Specifications and Tests (Airborne Equipment)", April 1979, will be updated using the information obtained from the test data.

6.5.1 Test Objectives. The primary objective for the testing was to determine the acceptable test limits for airborne high voltage components. The secondary objective was to evaluate each type of test and determine whether it is a destructive test or an evaluation test.

Tested components were to be unqualified commercial devices that may be tested to destruction to meet the above goals. The destructive tests were dielectric withstanding voltage and pulse tests.

6.5.2 Insulation Resistance. These tests are usually taken at low voltage (500 volts dc or less) and are used to determine the probability of short circuits and the current rating of the power source required for high-voltage dc testing. Components and short cable assemblies used in airborne and airborne-support high-voltage systems should have insulation resistance readings exceeding 500 megohms. All test articles exceeded that value.

Insulation resistance values specified in the criteria documents are compared to the test data as shown in Table 6.5-1. These data show that the values specified in the documents are much lower than the values obtained for the test articles. This implies that the criteria document data should be increased to the values shown for "New Criteria Document Values" in Table 6.5-1.

TABLE 6.5.1: INSULATION RESISTANCE

Components Test Article	Part Designation	Criteria Document, Megohms	Test Data, Megohms	New Criteria Document Value, Megohms
Cable	A-1	Not Specified	$2X10^6$	$1X10^6$/ft. length
	A-3		$2X10^6$	
Cable Assembly	A-1	500	$2X10^6$	$1X10^6$/ft. length
Capacitors	B-1	50,000	$1.25X10^5$	$1X10^5$
	B-2		$1.0X10^6$	
	B-3		$5.6X10^5$	
Connectors	A-2	500	$2.0X10^6$	$1X10^6$
Alternator Coil	D-1	Not Specified	0.7 to $2X10^6$	$1X10^4$
Transformer Coil	E-2	Not Specified	1000	1000

6.5.3 Capacitance and Dielectric Absorption. These tests are component rating verification tests used to evaluate the component quality. No changes are required for the criteria documents.

6.5.4 Dielectric Withstanding Voltage. The values listed in the High Voltage Criteria documents must be modified. Although all the components passed the specified dielectric withstanding voltage (DWV) tests, the capacitors were damaged by the test as determined by the high partial discharge readings. The cable assembly, cable, and connector test values are acceptable as recorded in the criteria documents. The compared data and new data are shown in Table 6.5-2.

Each test article should be tested for partial discharges before and after the DWV test to further evaluate the probability of damage to the test article.

TABLE 6.5-2: DIELECTRIC WITHSTANDING VOLTAGE (DWV)

Component: Test Article	Component: Part Designation	Rating, kV DC	Test Specified, kV	Voltage Passed, kV	Proposed Value, kV	% Rated Voltage
Cable	A-1	90	144	144	144	160
	A-3	60	100	100	100	160
Cable Assembly	A-2	90	144	144	144	160
Connector	A-3	60	100	100	100	160
Capacitor	B-1	100	200	200	160	160
	B-2	100	200	200	160	160
	B-3	80	160	160	128	160
Alternator Coil Sections	D-1	2.8	3.6	3.6	4.5	160
Phase-to-phase	D-2	29.6	48	24.7(air)	48	160
Pulse Transformer	E-2	20	40	45	32	160

6.5.5 Pulse Test. More information was gained from the pulse test than from the DWV test. First, the values specified in the criteria documents are too high, and second, a high voltage pulse may permanently damage the insulation system in the vicinity of a bonding flaw. Pulse test data corrections to the criteria documents are shown in Table 6.5-3.

TABLE 6.5-3: PULSE TEST COMPARISON

Components Test Article	Part Designation	Rating, kV DC	Test Voltage Specified, kV	Passed, kV	Proposed Value, kV	% Rated Voltage
Cable	A-1	90	360	120 failed	180	200
Cable Assembly	A-2	90	360	120 failed	180	200
Cable Assembly	A-4	60	210	50 68 failed	120	200
Connector	A-3	60	210	45 60 failed	120	200
Cable	A-5	17	34	35	34	200
Connector	A-6	17	34	35.5	34	200
Cable Assembly	A-7	17	34	34.0 50 failed	34	200
Capacitor	B-1	100	400	110 165 failed	175	175
	B-2	100	400	110 210 failed	175	175
	B-3	80	400	51 failed	190	175
	C-1	15	60	14.5	26	175
Alternator Coil Sections	D-1	2.8	5.6	11	5.6	200
Phase-to-Phase	D-2	29.6	106	50 60 failed	60	200
Pulse Transformer	E-2					
Primary to Ground		20	32	6 failed	-	-
Secondary to ground		200	320	210failed	-	-
Pri-to-sec		20	32	64	25	-

The proposed values for the components are easily justified since each of these items must be capable of withstanding the normal line transients imposed upon these components. Crowbar circuits and vacuum tube (when used) shorts can generate transient peak values of 160% normal line voltage (Reference 2). In addition, insulation systems should be capable of withstanding short duration peaks (less than one second) 20% higher than the one minute DWV peak voltage.

Examples of a cable assembly insulation system damage by pulse testing are shown in Figures 6.5-1 through 6.5-5. The first example shows the damage to test article A-2, a 90 kV cable assembly.

The cable assembly A-2 was tested to 120 kV peak. Following the test, the test data waveform indicated an insulation breakdown. The cable was examined and a puncture was visible at the cable shield termination, Figure 6.5-1. The termination was dissected and the insulation flaw was found to be between the primary insulation and the shield extending into the primary insulation toward the inner conductor, Figure 6.5-2. In Figure 6.5-3, the delaminated insulation system is exposed. Shown is a crack and a very dark spot where the arcing occurred. The bright area indicates an unbonded section near the shield termination - an air filled void.

The second cable assembly A-4 also failed the pulse test. Following the test, the cable was examined for visual failure. A smokey haze was found on the connector termination. The termination was unassembled and the parts examined. In Figures 6.5-4 and 6.5-5 are shown the inner surface of the connector shell and the braid. Both show indications of the internal insulation failure. The insulation was badly charred between the braid and inner conductor.

Cable assembly A-7 was submerged in a container filled with transformer oil as shown in Figure 6.5-6. The test article was connected as a cable by connecting the connector shell to the center conductor. In this configuration it passed the 34 Kv pulse test. It was then configured to test the connector by connecting the cable center conductor and shield braid to the high-voltage test terminal. Again it passed the 34 kV pulse test. The last configuration was to apply voltage to the cable assembly. That is, ground the cable braid and the connector shell and apply the pulse to the center connector. The cable assembly passed the 34 kV pulse test. When subjected to a 50 kV pulse test, the connector arced

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Reference 2. "Transmitter Transient Study"
Boeing memo, J. Fitch to W. G. Dunbar

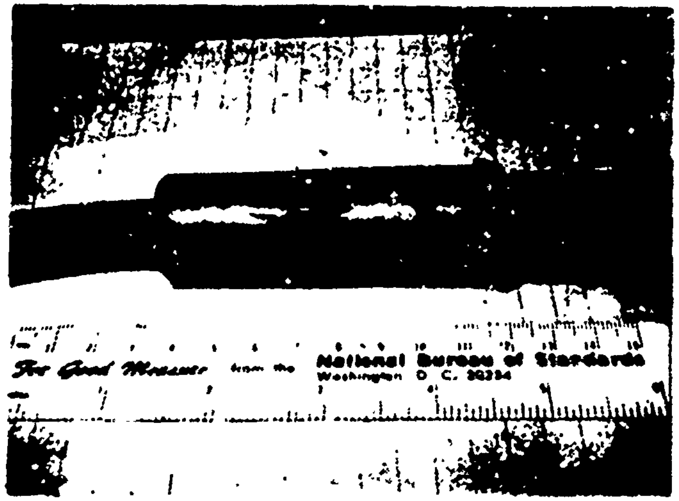

Figure 6.5-1: Cable Assembly A2 Pulse Test Failure

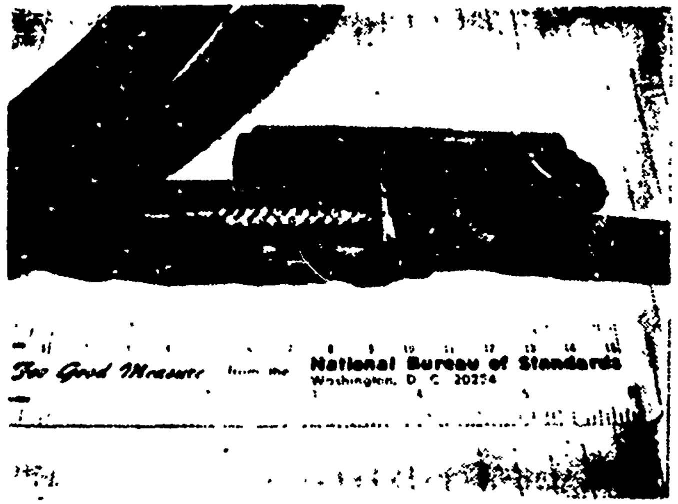

Figure 6.5-2: Shield Bond Failed

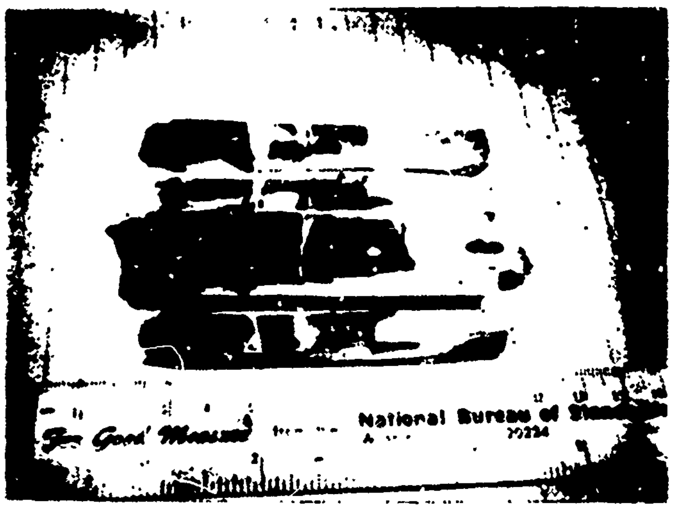

Figure 6.5-3: Detail of Bond Faliure

Figure 6.5-4: Cable Assembly A-4 Pulse Test Failure Showing Resid› › on the Connector Shell

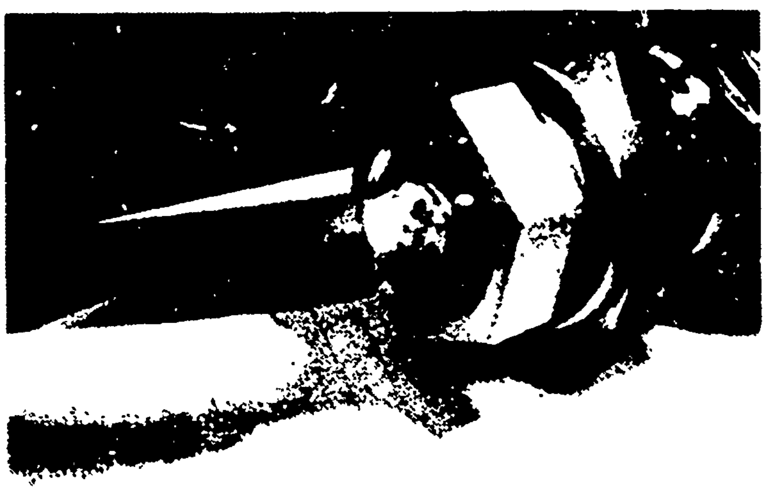

Figure 6.5-5: Failure Occurred Between Braid and Center Conductor

Figure 6.5-6: Connector A-6 Prior to Pulse Breakdown Test

Figure 6.5-7: Cable Assembly A-7 Prior to Pulse ...

over as indicated by the oil bubbling and swirling in Figure 6.5-7. A few minutes later the destroyed connector part and carbon was visible as shown in Figure 6.5-8. Photos of the connector before testing (Figure 6.5-9) and after testing are shown in Figures 6.5-10 and 6.5-11. Note the 0-rings and insert insulations were destroyed by the 50 kV pulse.

<u>Pulse Transformer</u>. Pulse tests should not be applied through the pulse transformer secondary coils. The high inductance of coils prohibits an even voltage distribution across the turns of the coils. Most of the pulse will be across the turn near the pulse initiation terminal, with the per unit volts per turn decreasing toward the grounded termination. The primary coil is purposely wound with low inductance (few turns) and resistance and must respond to a direct applied pulse.

Insulation between turns, coils and the core are designed to withstand the surge voltage stresses. Therefore, external pulse tests should only be applied to the primary and to the insulation between:

a) primary to secondary,
b) primary to ground (core),
c) secondary and primary (tied together) and ground (core).

Applying a pulse voltage to the secondary of the pulse transformer coil resulted in a failure which was caused by the unequal distribution of voltage across the turns in the winding as shown in Figure 6.5-12 to 6.5-18. The high inductance of the turns to the wave front (high-frequency) started an arc from the high voltage termination and half way across the insulated surface of the insulation where it penetrated the insulation between turns (Figure 6.5-12). Photos of the insulation damage to the three layers insulation are shown in Figure 6.5-13. The first layer (outer) turns sustained damage on both ends of the winding as well as damage through the three insulation layers (Figure 6.5-14). As the arc penetrated the coil, it damaged all the insulation between winding layers as shown in Figure 6.5-15 through 6.5-18.

Insulation testing between coils (primary and secondary) and between coils and the core/ground did not result in extensive damage. Likewise, the primary is designed to accept the stresses applied by the pulse voltage.

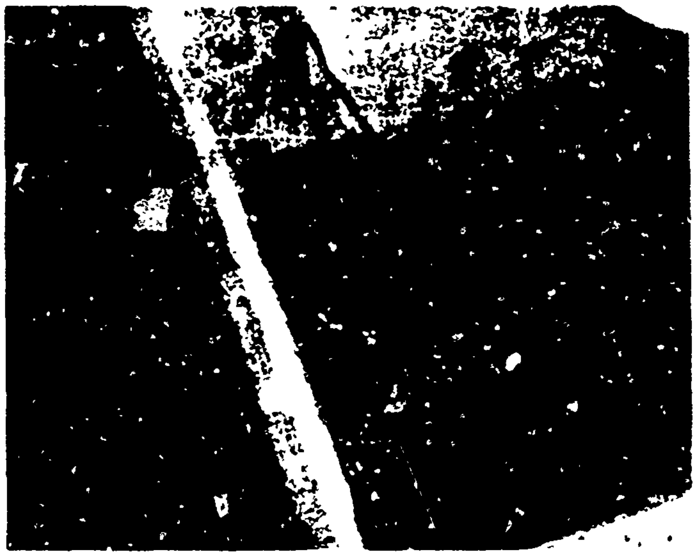

Figure 6.5-8: Breakdown of Connector A-6 Under Oil With 50kV Charge Applied From the Pulse Test Circuit

Figure 6.5-9: Cable Assembly A-7 After 50kV Pulse Test

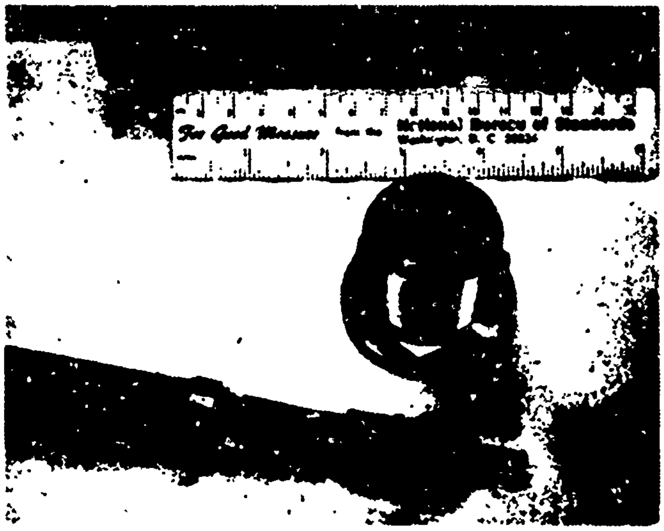

Figure 6.5-10: Front View of Connector A-6 After 50kV Pulse Test

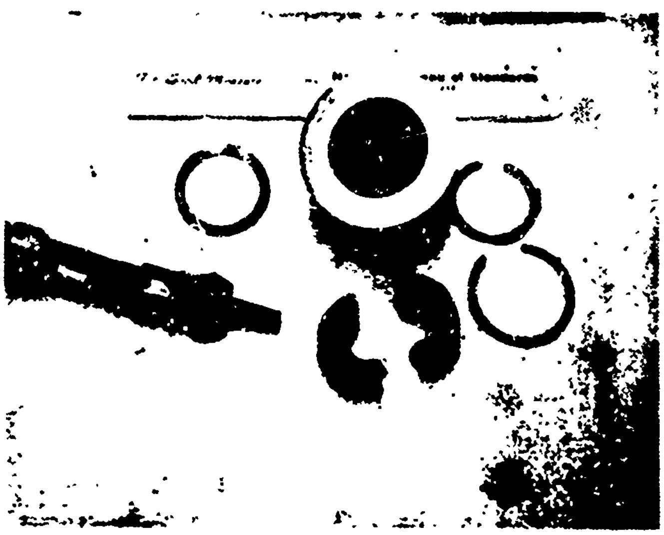

Figure 6.5-11: Dissection of Connector A-6 After Pulse Breakdown Test

Figure 6.5-12: Nomex Layers Between 1st and 2nd Secondary Layer Windings Showing Carbonized Path

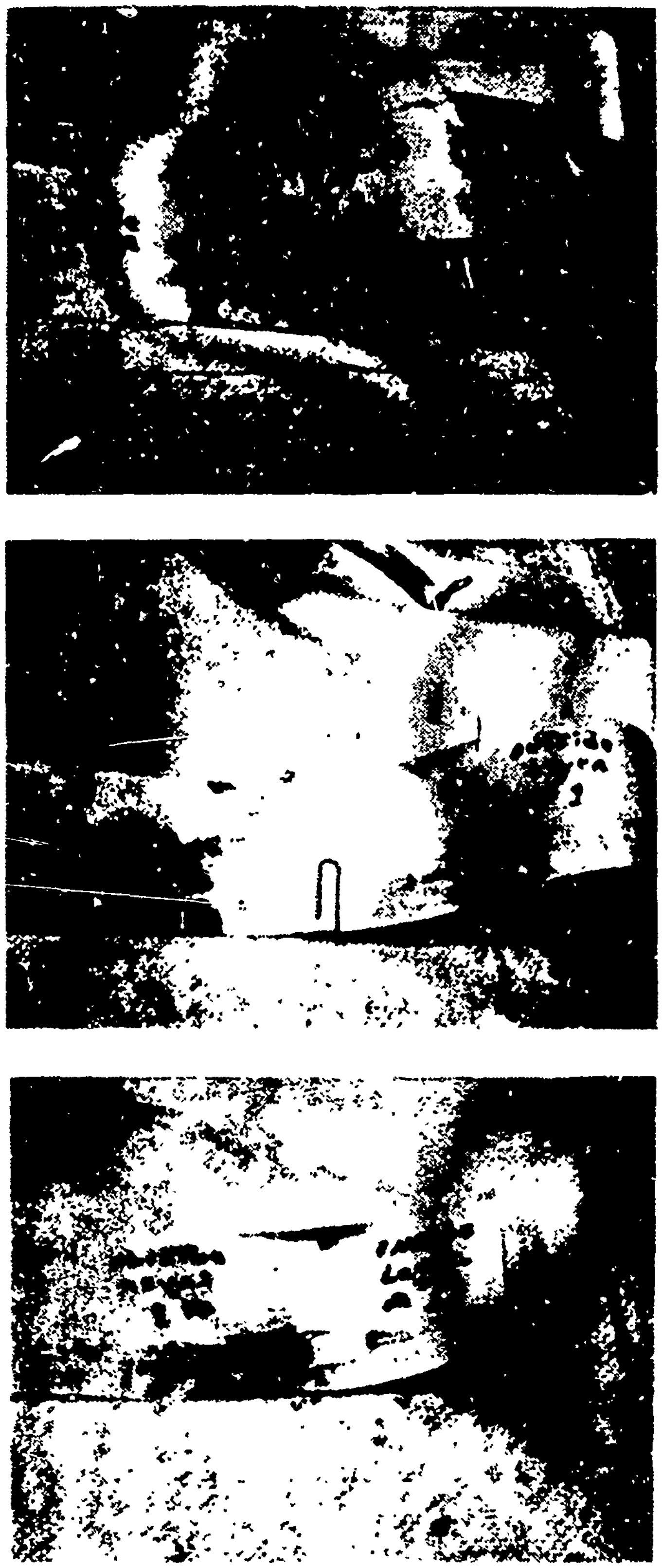

Figure 5.6-13: Unwound Nomex Between 1st and 2nd Secondary Layer Windings Showing Punctures and Carbonized Path

Figure 6.5-14: Secondary Layer Winding Showing Initiation of Arc Points on Either End of the Winding

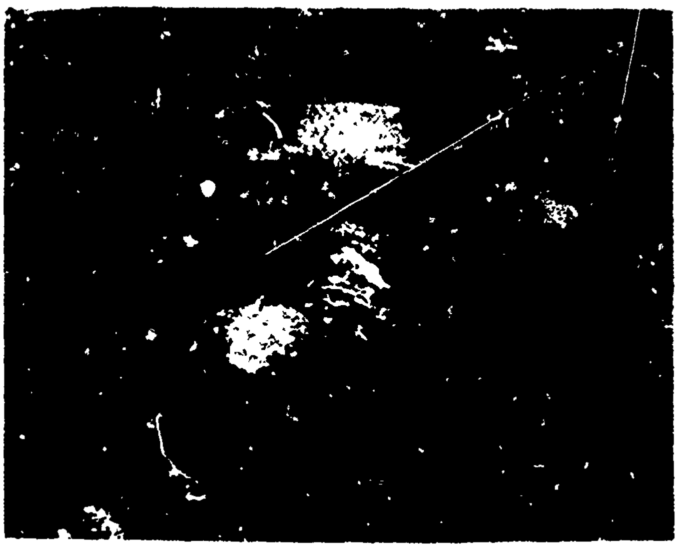

Figure 6.5-15: Secondary Layer Winding Showing Inception and Termination Points of the Arc

Figure 6.5-16: Unwound Nomex Between 3rd and 4th Secondary Layer Windings Showing the Puncture

Figure 6.5-17: Secondary Layer Winding With Multiple Punctures

Figure 6.5-18: Partially Unwound Outer Primary Winding Showing Puncture

Secondary winding pulse testing should be accomplished by an induced voltage test. The over-voltage pulse test to the primary would also be over-voltage pulse test to the secondary simultaneously, it would also test the insulation between the windings along with the insulation between the winding and the primary/secondary to core (ground).

Alternator Phase Coils. Two coils were installed on an alternator rotor jig as shown in Figure 6.4-3. The fiberglass epoxy spacers were placed between the coils to simulate the insulation system in an alternator. During the test it was found that extra surface was required to prevent surface tracking at high voltage. This extra surface was developed by adding Kapton insulation to the edges of the spacers.

The test voltage was calculated in accordance with the newly revised IEEE test standard as published at the 1981 Power Engineering Society Winter meeting as shown below.

The test results show that the insulation system is acceptable at 60 kV peak using the 1.2 microsecond rise pulse. These test results should be considered a worst case analysis because the windings in the actual machine would be completely potted.

For a 1.2 microsecond pulse the test voltage should be:

$$
\begin{aligned}
t &= 1.2 \text{ microsecond} \\
V_2 &= 0.5t + 1.9 \quad \text{per unit surge voltage} \\
&= 0.5\,(1.2) + 1.9 \\
&= 2.5 \text{ per unit} \\
V_2 &= 2.5\sqrt{2/3}\, V_L \\
&= 2.5\sqrt{2/3} \times 29.6 \\
&= 60.2 \text{ kV}
\end{aligned}
$$

Calculated value = 60.2 kV

Test value = 56 kV pass

61 kV pass

Reference 3, "Impulse Voltage Strength of AC Rotating Machines", IEEE Committee Report, PES Winter Power Meeting 1981, Paper 81WM 182-5.

Since there was trouble with the test setup, it was decided to test the insulation slabs which were used to separate the coils. The two test slabs passed 65 kV and 90 kV, respectively. Specimen #1 was tested and some tracking burns existed on the slab.

6.5.6 Partial Discharge Test. The partial discharge test data indicate that test articles damaged by DWV or pulse testing have very high partial discharge test signatures. This is an indication that more voids or insulation separations exist either by delamination as in the case of cable assemblies, or by the liquid being forced from weak areas within the capacitor foils. All capacitors, cables, and cable assemblies that indicated pulse test damage had higher than normal picocoulomb readings.

6.5.6.1 DC Tests. A capacitor with no indication of pulse test or DWV test damage (C-1) had very low dc picocoulomb readings. Likewise, connector A-3 had very low dc readings.

The actual test data shown in Appendix E has a multitude of counts at picocoulomb readings less than 0.6 picocoulomb. Most of these counts were caused by laboratory background noises generated by transformers, wiring, and other electromagnetic interference from electronic systems within the unshielded portion of the laboratory. The large power supply used for high-voltage testing was unshielded.

Listed in Table 6.5-4 are the dc partial discharge specified values, test values, and new values proposed to update specifications for the eight test articles. Only three specifications require change: capacitors, alternators, and transformers. The open coils of the alternator will permit generation of greater quantity and magnitude of partial discharges. The capacitor maximum peak values should be reduced to 100 pc rather than 1000 pc to be more consistent with the other test values achieved. Likewise, the transformer peak values based on dc testing should be increased.

6.5.6.2 AC Tests. The generator coils, pulse transformers, and cable assembly listed in Table 6.5-5 were tested for partial discharges using ac voltages. The generator coils are insulated with a glass impregnated matrix with the edges of each coil exposed to atmospheric conditions. Therefore, partial discharges will be generated within the glass matrix and in the air space across the coil edges. These values may approach or exceed 400 picocoulombs. These large readings, although undesirable, will not damage the glass matrix insulation within the allowable 100 to 1000 hours lifetime of the insulation system.

TABLE 6.5-4. DC PARTIAL DISCHARGE DATA SUMMARY

COMPONENTS		PARTIAL DISCHARGES -- (PC) AT RATED VOLTAGE							
		Specified			Test		Proposed		
Test Article	Part Designation	Max No.	Pc/Minute	Not to Exceed	Count/Minute at 10 PC	Peak PC	Limit PC/kV	Counts/Min Over Limit	Not to Exceed PC/kV
Cable	A-1	10	1	50	1	40	1	1	5
Cable Assembly	A-2	10	1	50	Failed		1	1	5
	A-4				2	5			
Connector	A-3	10	1	50	30	4	1	1	5
Capacitor	B-1	10	1	1000	2	40	1	1	2
	B-2				13	4	1	1	2
	B-3				Failed				
	C-1				1	2	1	1	2
Alternator									
Coil-to-Coil	D-1			50	1	350	15	5	30
Phase-to-Phase	D-2			500					
Pulse Transformer									
Primary to Secondary	E-2			50	1	20	1	1.0	2

TABLE 6.5-5 AC PARTIAL DISCHARGE DATA SUMMARY

TEST ARTICLE	PART DESIGNATION	PARTIAL DISCHARGES (PC) AT RATED VOLTAGE								
		SPECIFIED			TEST			PROPOSED		
		MAX PC	COUNTS/ MINUTE	NOT TO EXCEED PC	COUNT MINUTE	@ PC	PEAK PC	LIMIT PC/KV	COUNTS/ MIN OVER LIMIT	NOT TO EXCEED PC/KV
ALTERNATOR										
Coil-to-Coil	D-1			50	1		350	10	5	50
Phase-to-Phase	D-2			500	1		500	15	6	30
Cable	A-2	10	1	50	0	10	86	2	10	5
Cable	A-5	10	1	50	4	20	40	2	10	5
Connector	A-6							2	10	5
Cable Assembly	A-8	10	1	50	6	20	37	2	10	5

In a large system there will be several ac and dc voltage levels. The component evaluation testing indicates the higher voltage components will have higher picocoulamb signatures than the lower voltage components, that is, the higher the test article rated voltage, the higher the number of counts and the higher the maximum picocoulomb partial discharge. A value of 2 PC/KV is reasonable for large, long cables and very large transformers with life less than 1000 hours. For longer life components the count and picocoulomb values must be reduced to 1 PC/KV or less.

Indications of damage or life degradation were shown in Table 6.4-15 for the tests made on cable assemblies A-8 and A-9. Cable A-8 is a new cable and cable A-9 is a cable previously subjected to 2×10^9 pulses. The tests indicated only background noise at 9.4 KV for the new cable (less than 10 PC) and 12 counts at 500 PC for the used cable. The latter is a true indication of damage to the cable. From these data it can be assumed that an increase of 10 times the new component pc signature is an indication of damage. An increase of over 100 times the new component pc signature is an indication that the component is approaching end-of-life.

Typical pc signatures for cable assembly A-7 at 6 KV and 7.4 KV and 400 Hz are shown in Table 6.4-15 and Figures 6.5-19 and 6.5-20.

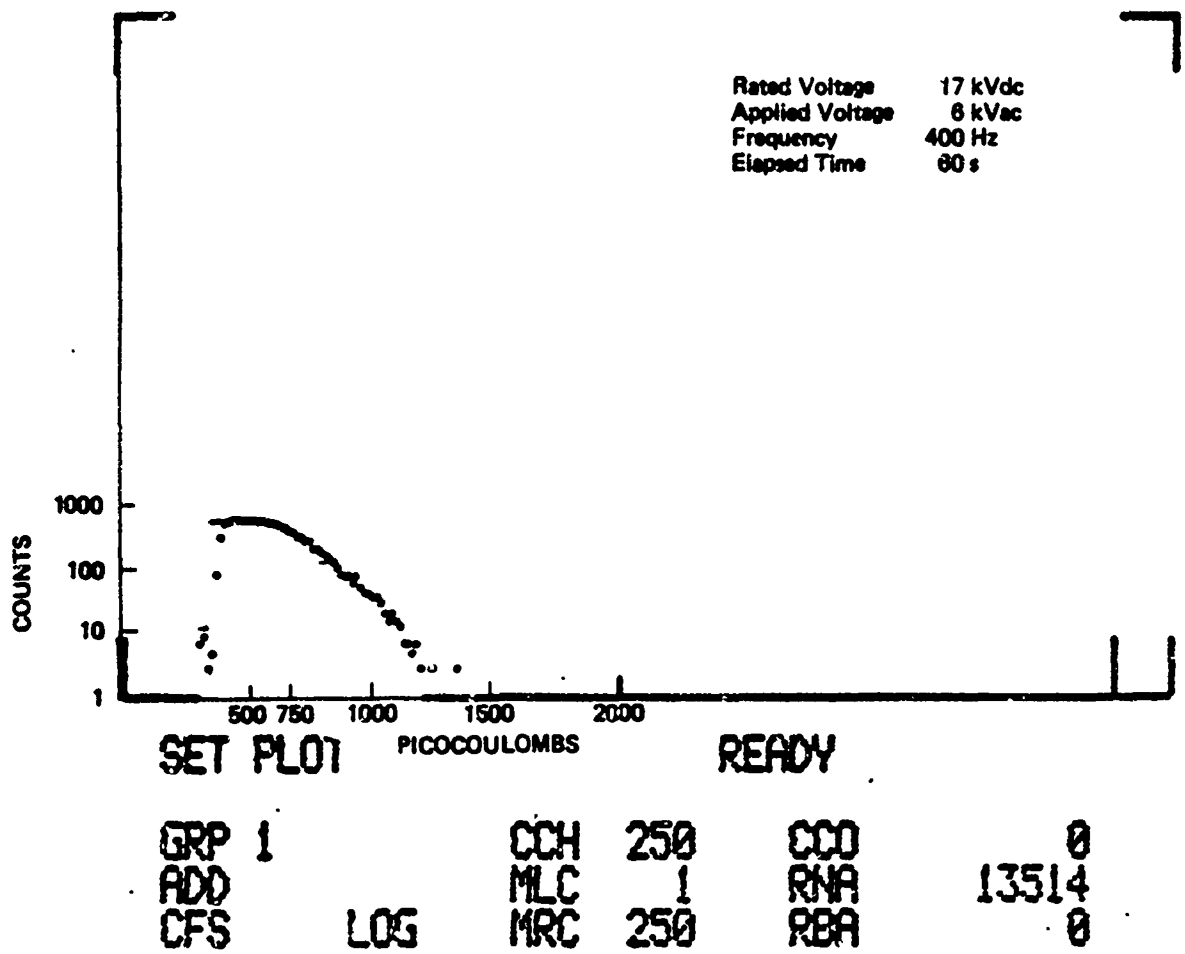

Table 6.5-19: Cable Assembly A-7 Picocoulomb Signature

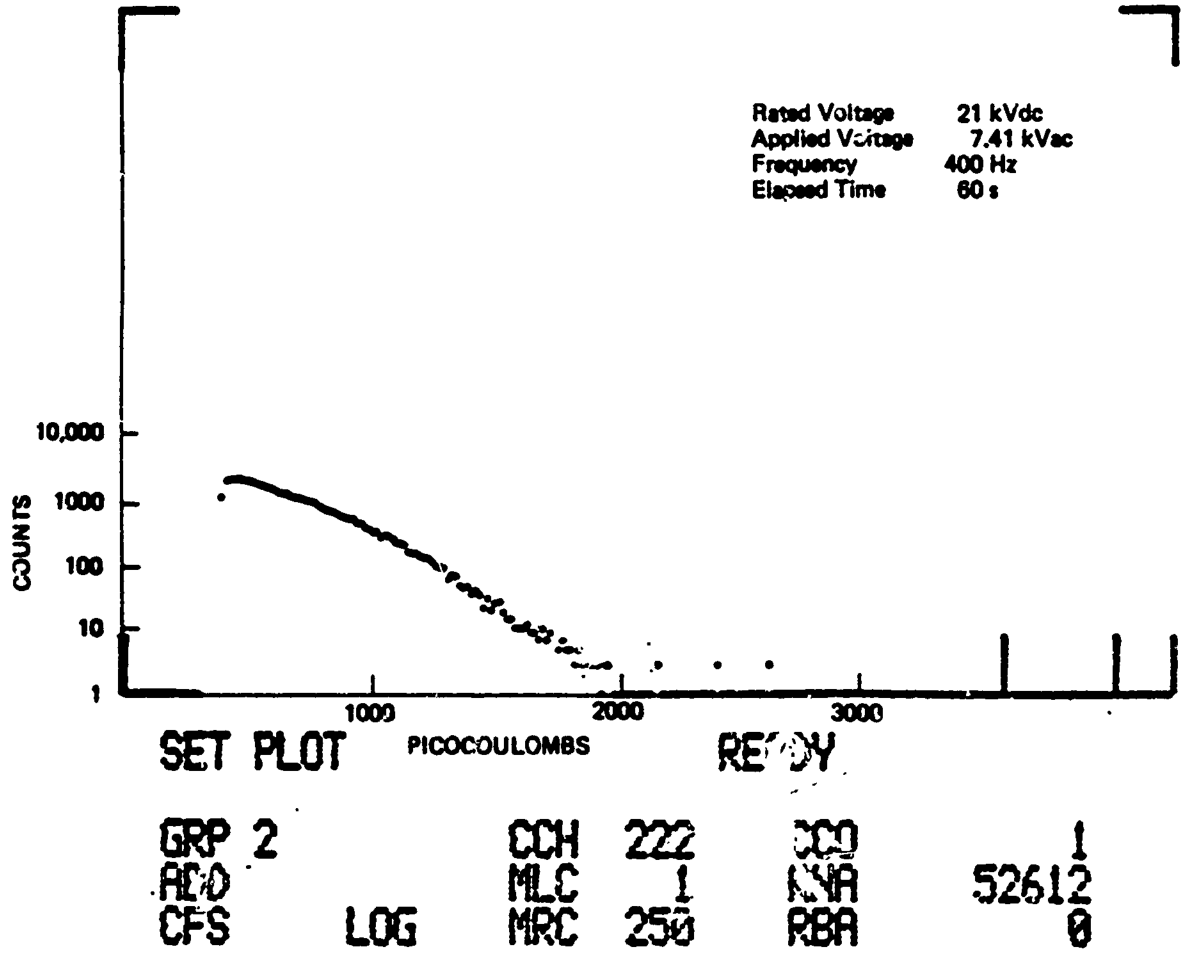

Table 6.5-20: Cable Assembly A-7 Picocoulomb Signature

7.0 CONCLUSIONS

Based on the test articles evaluated in this program, the following summary statement, overall conclusions, and results are presented.

- The high-voltage test articles were subjected to the insulation resistance, capacitance, dielectric withstanding voltage (DWV), pulse, and partial discharge tests as specified in the High Voltage Criteria Documents published in the USAF document AFAPL-TR-79-2024. It was found that the insulation resistance and capacitance test methods and parameters are acceptable. The partial discharge and dielectric withstanding voltage test methods are acceptable but the parameters must be revised, and the pulse test parameters must be revised.

- The dielectric withstanding voltage parameter must be reduced to 160% component rated voltage.

- The pulse peak voltage must be limited to 200% component rated voltage. In addition, the pulse test time-voltage wave shape must be revised to the acceptable limits of test equipment and instrumentation. However, if more realistic wave shapes cannot be determined due to lack of system definition, the standard 1.2 X 50 micro second pulse shall be used.

- A new test sequence should be followed. The sequence should be:
  - insulation resistance
  - capacitance
  - partial discharge
  - dielectric withstanding voltage
  - pulse
  - partial discharge

- Based on the test results in this program, components passing the DWV and pulse tests should pass the second partial discharge test with less than 20% increase in maximum picocoulomb partial discharge magnitude and total number of counts in a one-minute test period.

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- Partial discharge magnitudes for the generator coils must be much higher than for shielded or contained components, such as cable assemblies and capacitors. Picocoulomb values to 500 pc are acceptable for the glass matrix materials.

- Generator cable assemblies and connectors must be tested separately and remain within the acceptable limits for the components.

APPENDIX A
DIELECTRIC WITHSTANDING VOLTAGE

Two cable assemblies, three capacitor, and two alternator coil segments were tested for dielectric withstanding voltage. The test results are shown in Table A-1. The coil segments were insulated as described in Paragraph 6.4.5. In addition, FUS-A-lab^R polyester and glass tape strips 6 mils thick were placed between the insulated surfaces to simulate the alternator coil wedge spaces.

Rel. Humidity = 58%

Parts		Serial Number of Parts	Test Frequency	Voltage Applied for 10 sec. Test #1	Voltage Applied for 11 sec. Test #2	Voltage Applied for 1 minute Test #3	Result in air	D-C Result in oil	D-C Impulse Voltage		Test
Cable Assy	w/o conn.	A-1	D-C	108 (kv)	125 (kv)	144 (kv)	arced 50 kv	ok			
	w/ conn.	A-2	D-C	108 (kv)	125 (kv)	144 (kv)	arced 50 kv	ok			
Cable Assy.	w/o conn.	A-3	D-C	72 (kv)	86 (kv)	100 (kv)	arced 65 (kv)	ok			
	w/ conn.	A-3	D-C	72 (kv)	86 (kv)	100 (kv)	65 (kv)	ok			
Capacitor 100 kv		B-1	D-C	160 (kv)	180 (kv)	200 (kv)	ok				
Capacitor 160 kv		B-2	D-C	160 (kv)	180 (kv)	200 (kv)	ok				
Capacitor 80 kv.		B-3	D-C	130 (kv)	145 (kv)	160 (kv)	ok				
Coils		No Insulation							<8 kv		I III IV
		1 Layer	60 Hz		6.0 (kv)				>8 (kv)		V
Coils		2 Layers	60 Hz		6.4 (kv)				>11 (kv)		VI
		3 Layers	60 Hz		6.8 (kv)				>11 (kv)		VII
		D-C Power Supply	200 kV	BC 365467							
		A-C Power Supply									
		Impulse, High "V" Divider		BC 369649							
		"O" Scope 7633	BEHC 30-021366								

CALC			REVISED	DATE
CHECK	Swc	8-80		
APR	Awo	8-80		
APR				

Dielectric Withstanding Voltage Test Data

APPENDIX B

PULSE TEST DATA FOR CABLES AND CAPACITORS

Two sets of pulse data were taken. High voltage pulse test to 225 kv peak were conducted by Technology/Scientific Services, Inc. personnel in the Electromagnetic Hazards Test Facility, AFWAL/FIESL, Wright Patterson AFB, Ohio, for the cables, cable assemblies, capacitor, and connector. The generator coils were tested at the Boeing Lightning Laboratory. Both sets of data are in this Appendix.

TECHNOLOGY SCIENTIFIC SERVICES, INC.
A SUBSIDIARY OF TECHNOLOGY INCORPORATED
P. O. Box 3065, Overlook Branch, Dayton, Ohio 45431
Tel. (513) 426-2405

November 20, 1980

TEST RESULTS OF TEST ARTICLES - CONTRACT No. F33615-79-C-2067.

LIST OF TEST EQUIPMENT USED:

A Marx Generator: 2-7 stages used, .35μfd - .1μfd, 35 KV-225 KV.

A Hipotronics Voltage Divider: Model RVD 1000

A Hipotronics Power Supply: Model #8100-25

A Hewlett-Packard Storage Oscilloscope: Model #1744A (100 MHz).

A schematic of the test setup is shown in Figure 14.

TEST ARTICLES AND RESULTS

#1. Cable Assembly, (A-2) and connector, A-4 (60 Kv)

Initial charge on the Marx generator was set for 120 KV as per test plan. ("Test Articles", Boeing memo 2-3743-OSWS-426. 27 October 1980).

The oscillograms show that the cable broke down at 75 KV. (See figures B1 and B2).

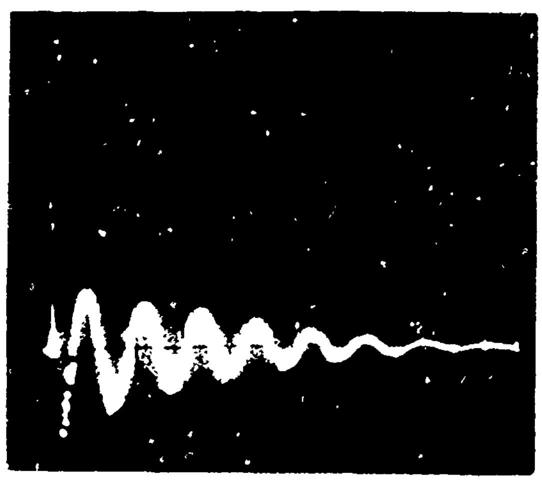


Figure B1. Vertical: 25 KV/div Horizontal: 5μsec/div
Oscillogram of First Shot onto Cable Assembly (≈75 KV).

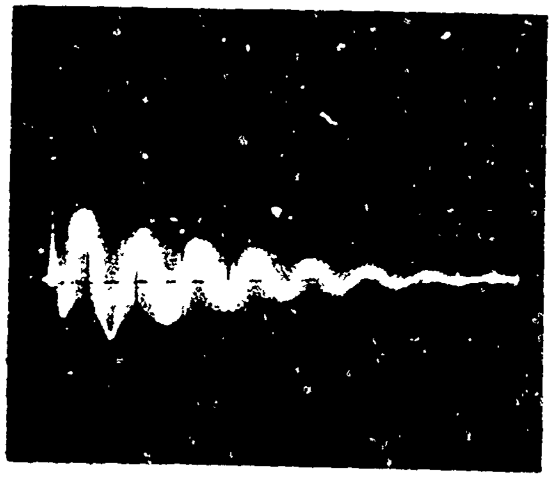


Figure B2. Vertical: 25 KV/div Horizontal: 5μsec/div
Oscillogram of #2 shot to Cable Assembly with
#1 Breakdown Point Put in Liquid Freon. (≈75 KV)

The connector was removed from the end of the cable assembly and the HV end was tested with the open end of the cable in the freon. Figures B3-B6 show the resulting impulse test results.

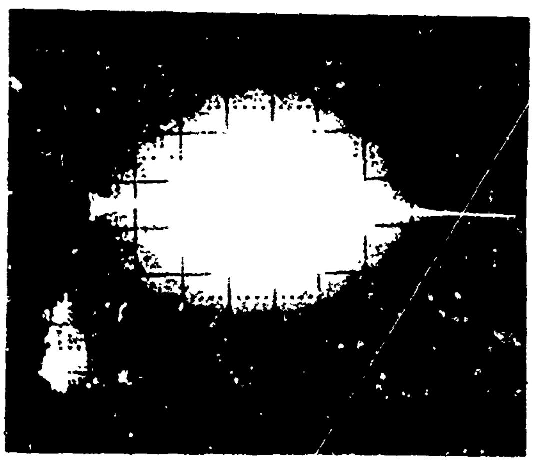


Figure B3. Vertical: 10 KV/div Horizontal: 2μsec/div
An Oscillogram of the Impulse Applied to Connector
With Cable Open End in Freon. (≈34 KV).

3

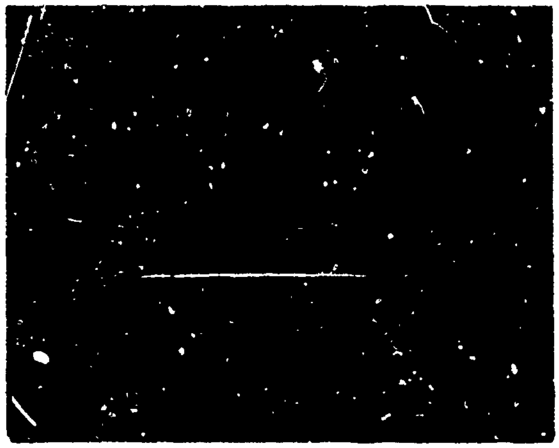


Figure B4. Vertical: 20KV/div Horizontal: 2μsec/div
A Repeat of Shot #3 to Verify Voltage Level(≈34KV).

Figure B5. Vertical: 10 KV/div Horizontal: 2μsec/div
Increased Voltage Applied to Connector Assembly and Cable Open End in Freon (≈ 45 KV).

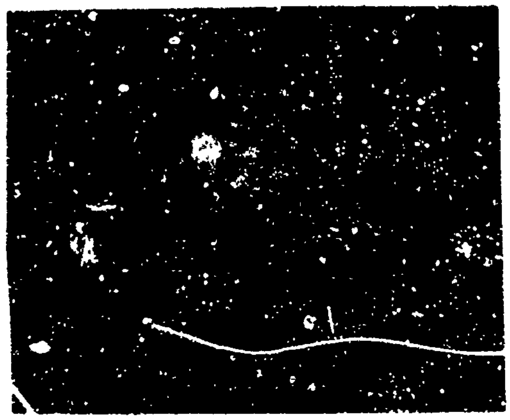


Figure B6. Vertical: 20 KV/div Horizontal: 2μsec/div
Breakdown Voltage Waveform on the Connector and Cable Assembly with Open End of Cable in Freon. (≈ 60 KV).

#2. The 40 KV Cable (A-4) and End Recepticles

A single pulse of 51 KV potential was applied to the assembly and it broke down at an estimated level of 43 KV. A poor quality trace was recorded on the oscilloscope which prevented an oscillogram from being obtained.

#3. Capacitor B-3

The Marx Generator was set up to discharge with a 51 KV peak voltage impulse waveform across the capacitor. The capacitor broke down prior to that level. Oscilloscope camera problems prevented an oscillograph of the results.

#4. Capacitor B-2

The initial test level on this capacitor was just under 60 KV. Due to previous corona testing it was felt that some dielectric polarization had taken place; since the B-2 capacitor had gone at such a low voltage. Thus the negative end of the capacitor was attached to the Marx. The Marx was being fired with a negative pulse. Figures B7-B11 show the applied voltage

impulse waveforms on the capacitor.

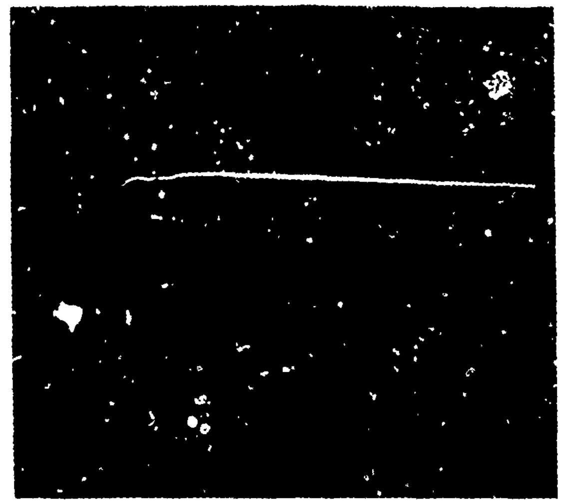


Figure B7. Vertical: 20 KV/div Horizontal: 2μsec/div
Initial Pulse Applied to Capacitor B-2,
Peaking at Approximately 58 KV.

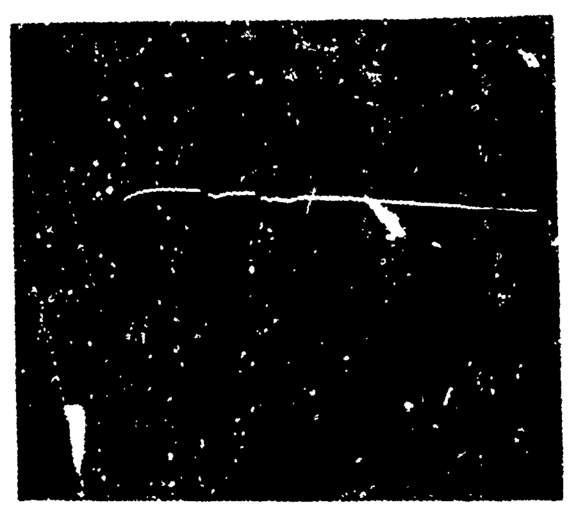


Figure B8. Vertical: 20 KV/div Horizontal: 2μsec/div
Second Level of Applied Voltage to Capacitor B-2 Peaking at ≈92 KV. Note: Slight Breakup in Decay Side of Waveform.

Figure B9. Vertical: 50 KV/div Horizontal: 2μsec/div
Third Voltage Level Applied to B-2
Peak Voltage ≈110 KV. No Break up of Waveform Noted.

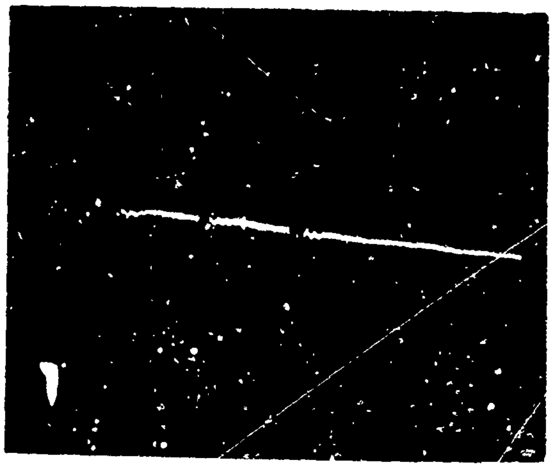


Figure B10. Vertical: 50 KV/div Horizontal: 2μsec/div
Fourth Level of Applied Voltage to B-2
Peak Voltage ≈155 KV. The Spiking Seen on the Decay Side is Due to Observed Arcing in the Discharge Circuit of the Marx Generator.

7

Figure B11. Vertical: 50 KV/div Horizontal: 2μsec/div
The Last Shot of Applied Impulse Voltage to Capacitor B-2 of Approximately 210 KV. Note Just at the Peak the Waveform Breaks Up. It was Felt That This Would be About The Upper Limit For the Dielectric Hold Off.

#5. Capacitor B-1

The capacitor was set up similiarly to the B-2 and it was checked to ensure that the negatively static tested lead was attached to the Marx Generator output. The initial level was about 100 KV. (See Figures B12 and B13).

Figure B12. Vertical: 50 KV/div Horizontal: 2μsec/div
Initial Pulsed Voltage Waveform Applied to B-2 ≈110 KV Peak.

Figure B13. Vertical: 50 KV/div Horizontal: 2μsec/div
The Second and Last Voltage Waveform Applied to B-1 with ≈165 KV Peak.
The Reason for the Last Shot is the Break Up of the Waveform Indicating That the Level is Close to Breakdown of the Capacitor's Dielectric.

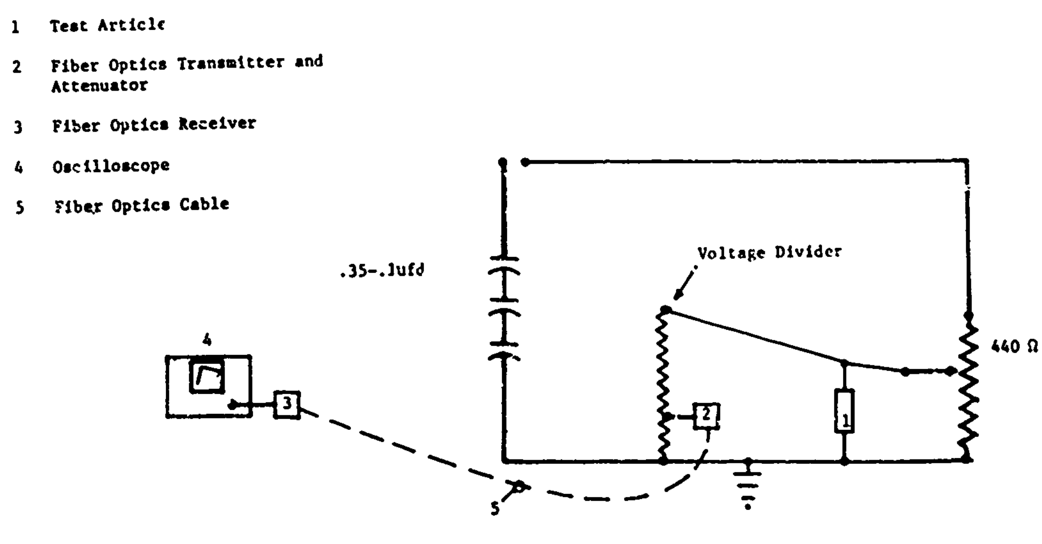


Figure B14. A Schematic Showing the Setup of the Marx Generator, Test Article Location, and Measurement System.

#6. Hughes Capacitor - HUG864014, Serial #13 (2.2μfd - 15 KV)

The capacitance of the Marx generator proved too low to test the Hughes capacitor, therefore, another generator needed to be set up. This consisted mainly of a 4μfd, 50 KV capacitor and discharge circuit. Figure 14a is a line drawing which shows the resultant circuit used.

1 - HV Probe

2 - Oscilloscope

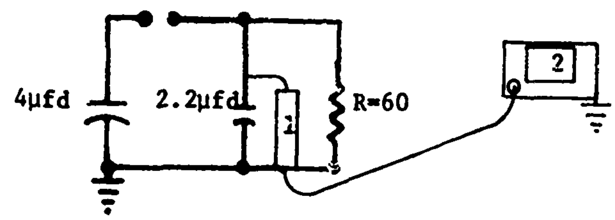


Figure B14a. A Schematic Drawing of the Circuit and Measurement System Used During the 2.2μfd Capacitor Test.

No specification on applied waveform was given, so a one microsecond front time with a 40-50 microsecond tail time was set up without the test capacitor added. Figure B15 shows the voltage waveform measured across the Hughes capacitor on the initial pulse of 7 KV.

Figure B15. Vertical: 2 KV/div Horizontal: 5μsec/div
The Oscillogram of the Pulsed Voltage Waveform Across the C-1 , Serial #13 Capacitor, 7 KV Peak.

Figure B15, shows a frequency riding the impulse of 100 KHz. The exact cause is not clear but the internal inductance of the two capacitors along with lead and connection inductance could be sufficient to cause the ringing noted. The equivalent capacitance would be 6.2μfd; with the 100 KHz signal, the inductance would be:

$$L = \frac{1}{(2\pi f)^2 C} = 0.409\mu h$$

The 60Ω resistor in parallel with the two capacitors effectively dampens out the oscillation in about 40 microseconds.

Another observation was that the charging voltage on the generator 4μfd capacitor was approximately 5 KV. There appears to be a voltage addition involved.

Figure 16 brings out an interesting waveform which may help to determine the addition mechanism. The charge voltage on the generator capacitor was set for 10 KV.

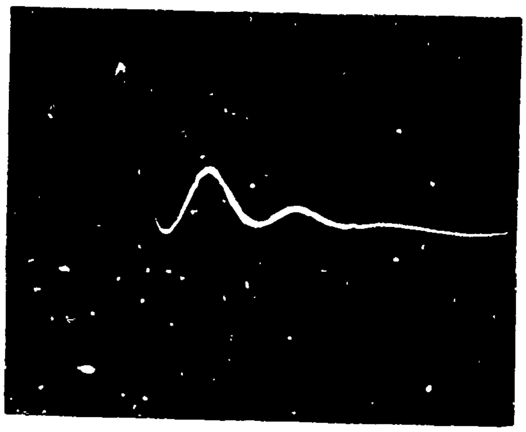
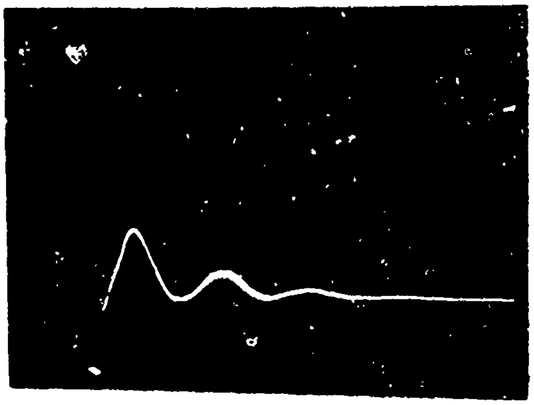


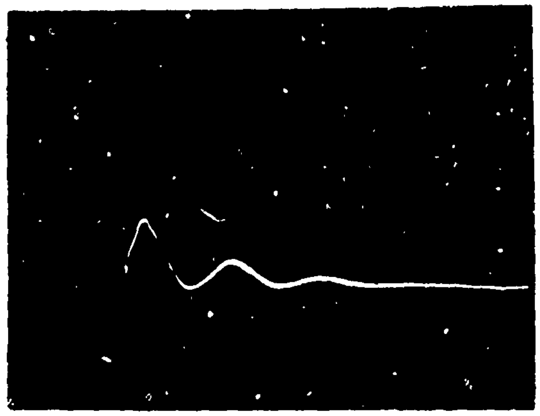
Figure B16. Vertical: 2 KV/div Horizontal: 5μsec/div
The Oscillogram of the Impulse Voltage as Applied to Capacitor C-1 , Serial #13. The Voltage Peak at 12.6 KV. The Oscillation is Present and Also, a Change in Rate-of-Rise of the Wavefront Can Be Seen.

The change in rate-of-rise is of great interest but an exact explanation is beyond the scope of this report, unfortunately.

The next test level was determined to be 11 KV on the charge capacitor which would keep us below the maximum rating of the Hughes capacitor of 15 KV. Figure B17 is a series of five oscillograms in repetition to determine if the shots close to maximum deteriorate the dielectric of the capacitor.



#1



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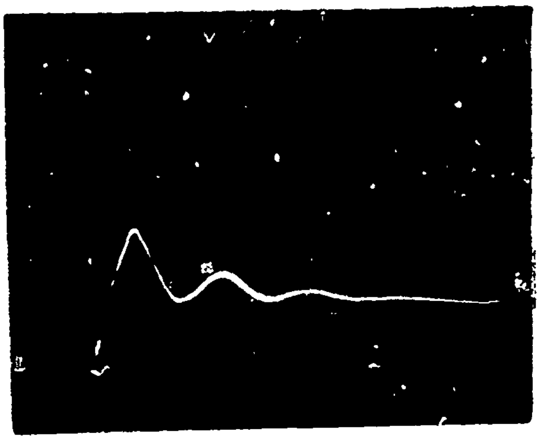

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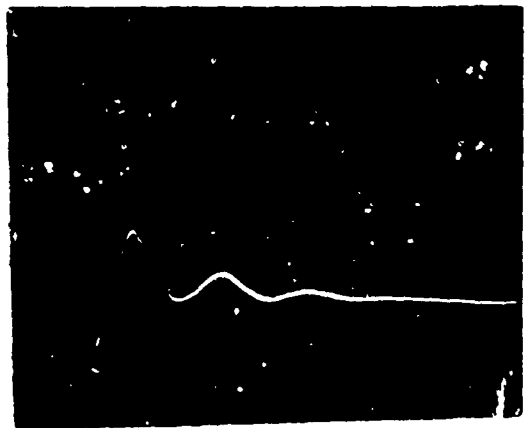

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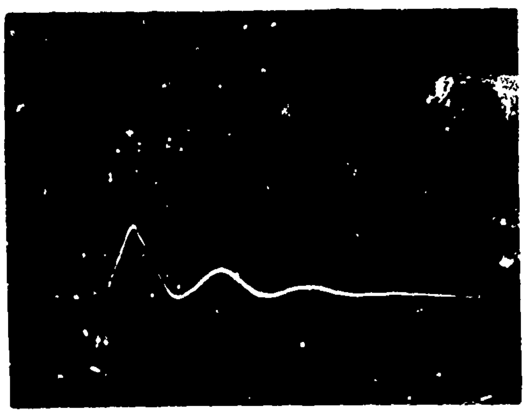


#5

Figure B17. Vertical: 5 KV/div
Horizontal: 5μsec/div

This Series of Oscillograms Shows the Waveforms of the Impulse Voltage Applied to the C-1
Serial #13 Capacitor with the Same Charge Voltage Each Shot. No Noticeable Deterioration in Waveform Was Noted After the 5 Shots - Voltage Peak ≈14.5 KV.

John G. Schneider

John G. Schneider
High Volta_e Test Engineer

APPENDIX C

PULSE TESTS FOR ALTERNATOR COIL SEGMENTS

Boeing Laboratory tests using short straight segments of alternator coils with various spacers, between coil segments, of 6-mil thick FUS-a-Fab^R polyester and glass tape. Fast pulses, having 500 nanosecond rise time to full voltage (negative) a fall to near 0 voltage in 2.5 microseconds.

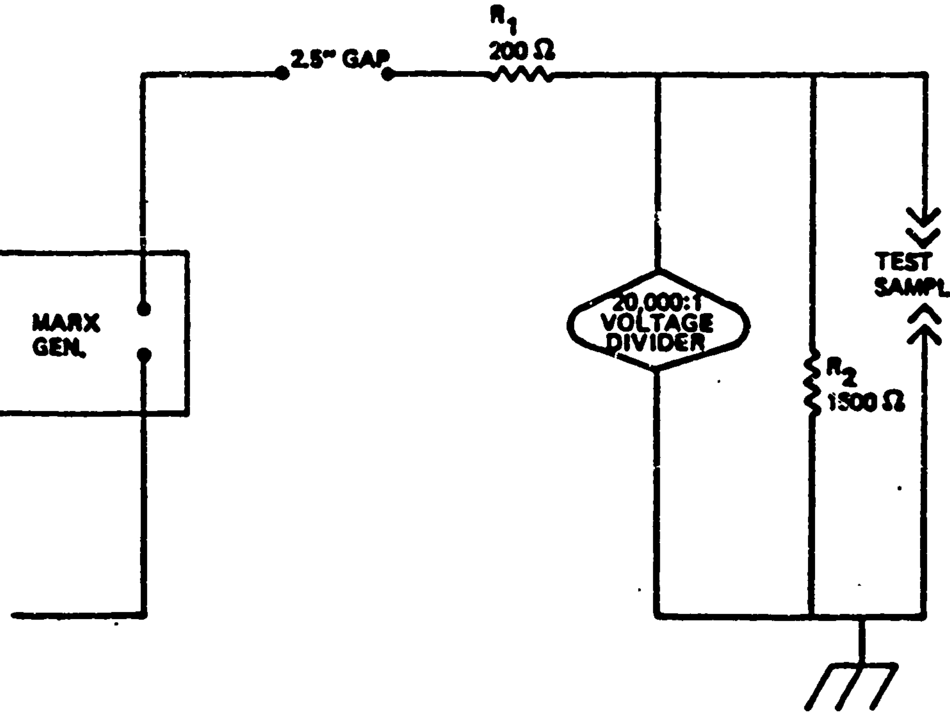
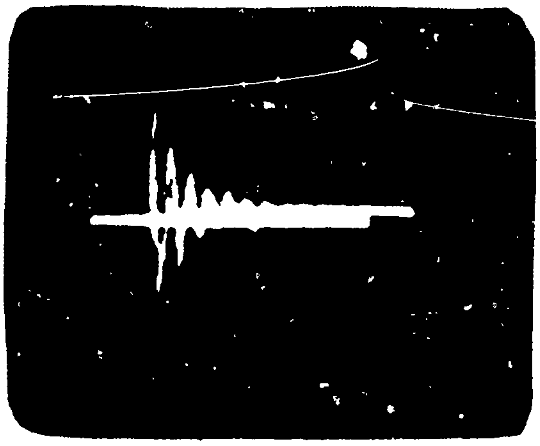
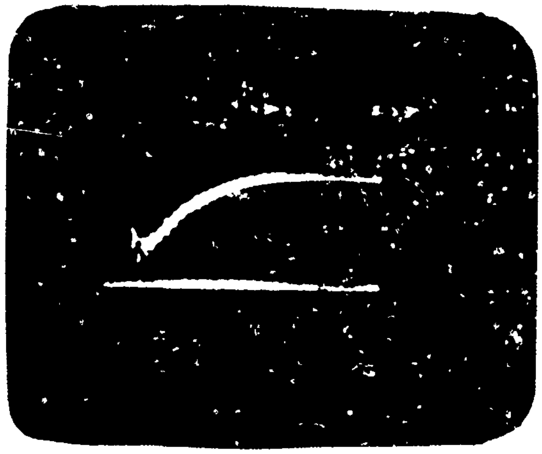


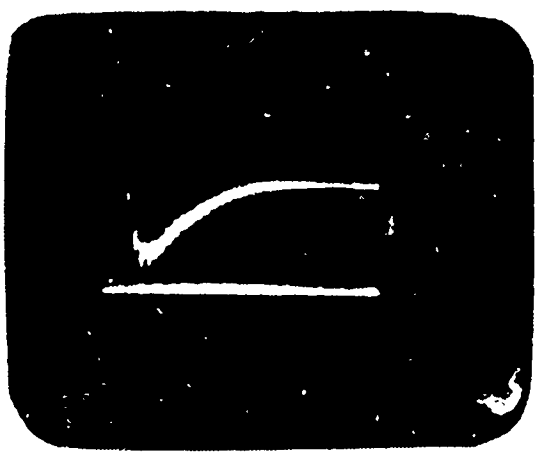
Figure C-1: Impulse Test Setup



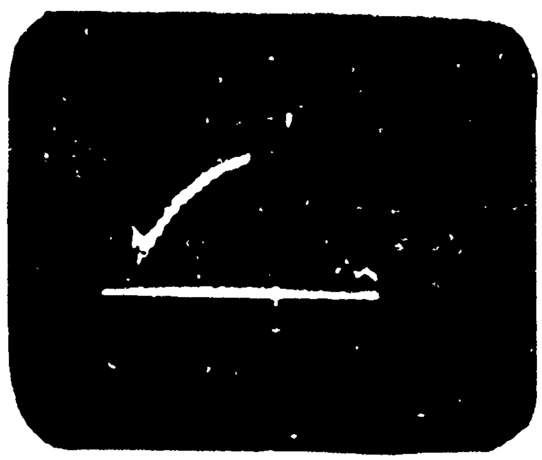
Generator Coil
Breakdown at 8.0
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



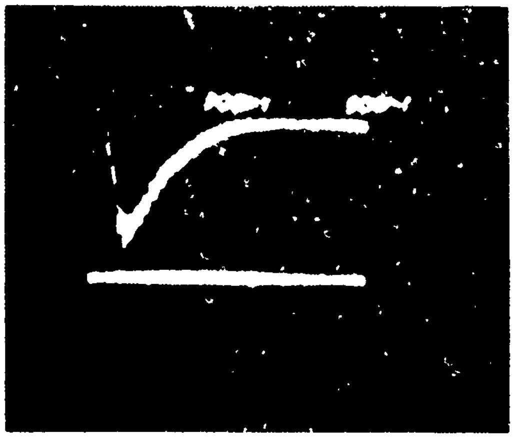
Generator Coil
1 Layer Insulation
Pass 8 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



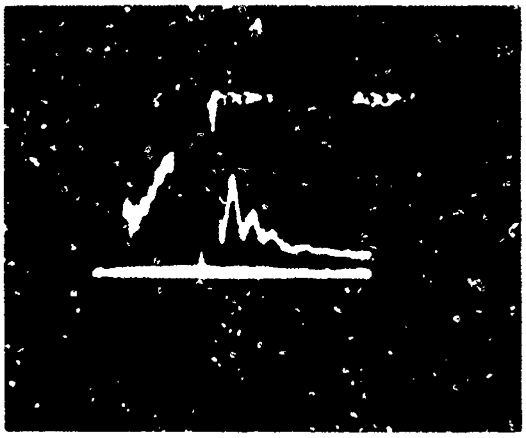
Generator Coil
1 Laye. ᵀnsulation
Pass 8 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



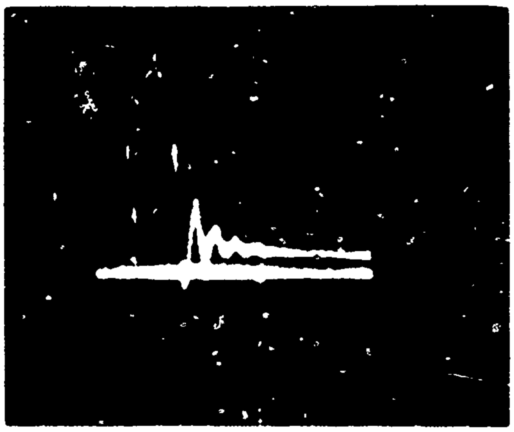
Generator Coil
1 Layer Insulation
Breakdown at 10 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



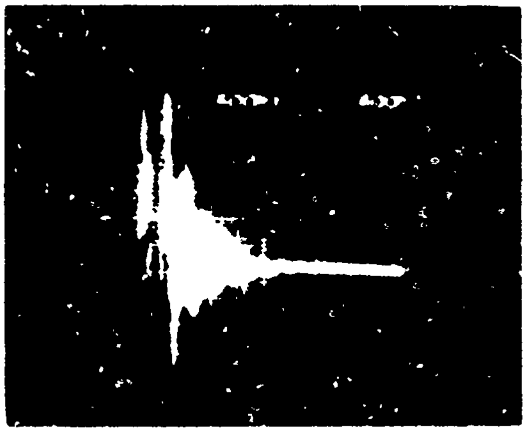
Generator Coil
2 Layers Insulation
Pass 11 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



Generator Coil
2 Layers Insulation
Breakdown at 13 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



Generator Coil
3 Layers Insulation
Breakdown at 16 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.



Generator Coil
3 Layers Insulation
Breakdown at 13 KV
Vertical: 2000 V/div.
Horizontal: 500 ns/div.

APPENDIX E

PULSE TEST DATA FOR PULSE TRANSFORMERS AND ALTERNATOR COILS

Two sets of pulse data were taken. High voltage pulse tests were conducted by Technology/Scientific Services, Inc. personnel in the Electromagnetic Hazards Test Facility, AFWAL/FIESL, Wright-Patterson AFB, Ohio.

SECTION 1

Surge Test data of a pulse transformer (E-1).

SECTION 2

Surge Test data of a pair of alternator coils on a test jig.

CTM-146-81-72

TECHNOLOGY/SCIENTIFIC SERVICES, INC.
A SUBSIDIARY OF TECHNOLOGY INCORPORATED
P. O. Box 3065, Overlook Branch, Dayton, Ohio 45431
Tel. (513) 426-2405

April 2, 1981

TO: Boeing Aerospace Company
P.O. Box 3999 Mail Stop 8K-75
Seattle, WA 98124

SUBJECT: Pulse Transformer High Voltage Impulse Test

Introduction

This report describes the work performed under Purchase Contract No. F95731 to Boeing through a subcontract with T/SSI. The task entailed high voltage surge testing of a pulse transformer. The tests that were performed followed the "Generator High Voltage Test Procedure" (Boeing test procedure). The tests were in accordance with U.S. Air Force technical document AFAPL-TR-79-2024, High Voltage Specification and Test (Airborne Equipment, April 1979).

Test Setup

The test called out two types of voltage waveforms to be used. First a "full wave" was to be used. This is the standard impulse test waveform (1.2 x 40 μs). The second waveform is a chopped version of the first.

Chopped indicates that, after a minimum amount of time on, a spark gap is fired (usually at a preset level) to prevent the full wave form being applied to the test specimen.

To perform this test, the 1.5 Megavolt Marx generator was used with some modifications to meet the voltage requirements. Also, a chopping gap was added to the output of the Marx to perform that phase of the test. Figure 1 is a schematic of the test circuit used.

The pulse transformer test consisted of three phases. The first phase was to check the performance from secondary high to secondary low from approximately 200 KV to approximately 400 KV. The second phase involved checking between the primary and secondary at 20 KV to 60 KV. The third phase involved checking the primary high to low hold off at approximately 20 KV.

During the initial set up of the transformer it was realized that the air gap between the output terminations of the trans-

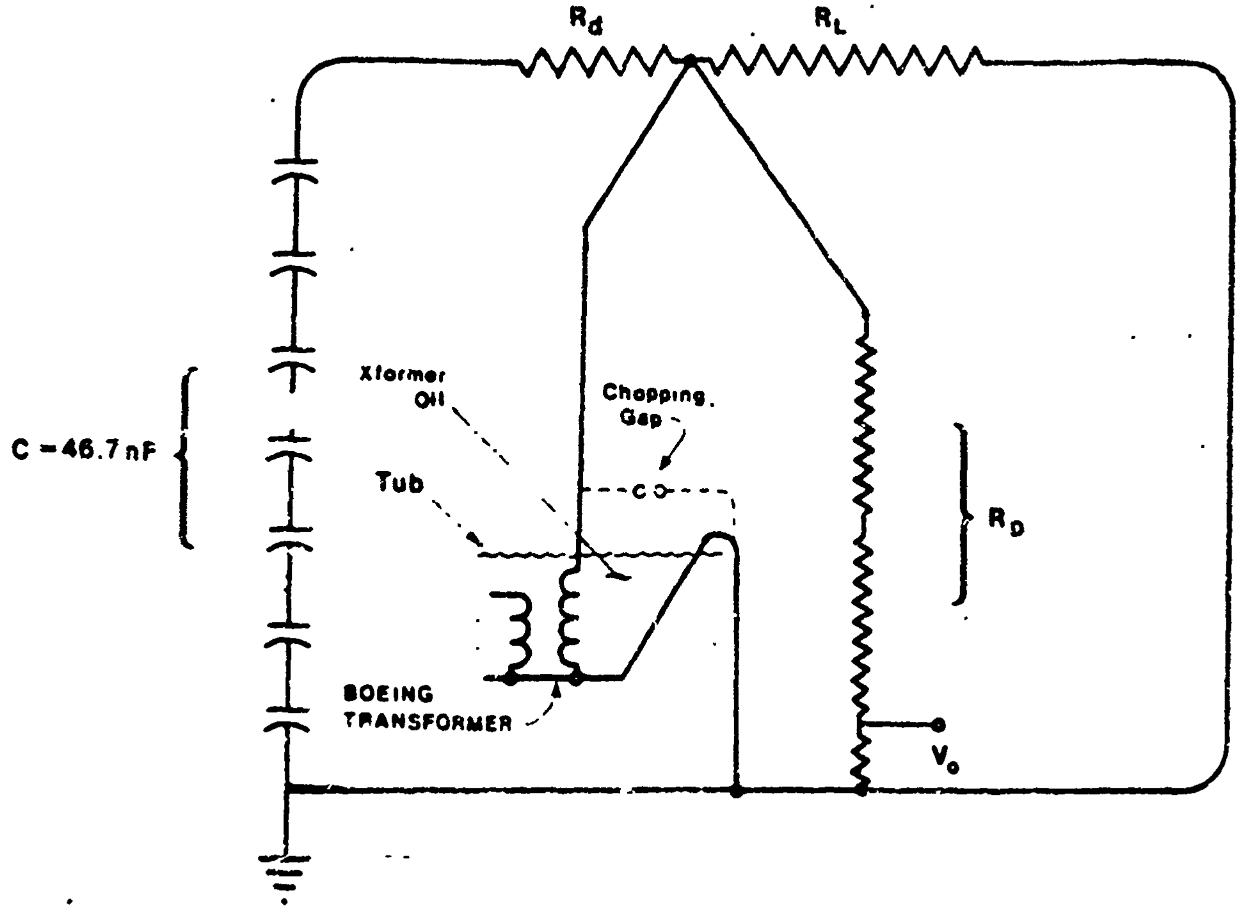


Figure D-1: Basic Test Circuit

former could not hold off the test voltage. It was decided to put the transformer into a dielectric container of transformer oil (OT Insulation 0:1, Electrical, VV-1-530A, Class 1, GSA 9160-00-685-0914, Gulf Oil Corporation). This was to help insulate the leads to allow the test voltage to reach the coil.

Test Results

Figure D2 shows the set up used to test the transformer during phase 1, secondary high to low. The first shot was set up to fire at 200 KV full wave; however, the Marx generator set up did not fire, therefore, the voltage was increased to 210 KV total output voltage (approximately 3 kilojoules of energy). Figure 3 shows the result. Light can be seen from the windings of the transformer and during the test a muffled explosion was heard coming from the dielectric container. (See table DI for summary of test results.)

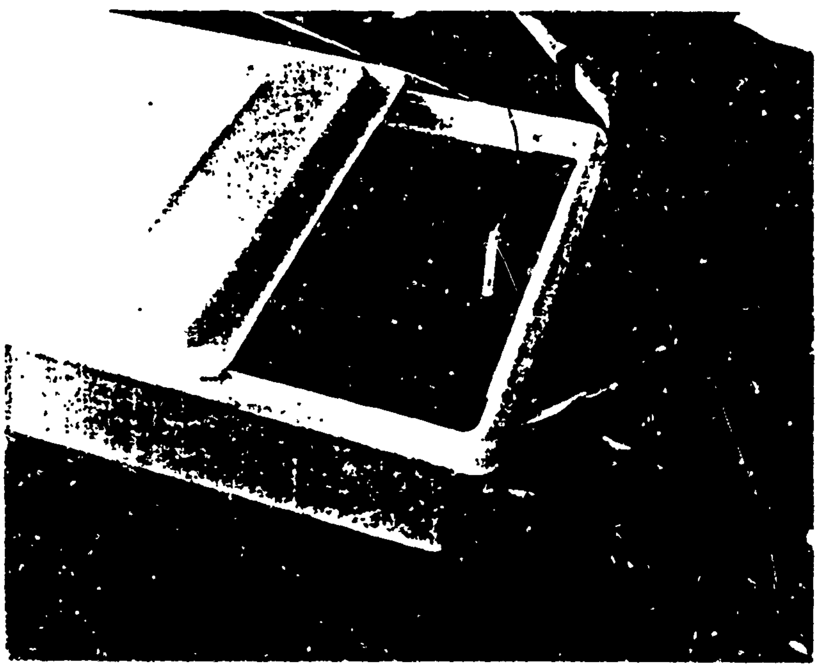


Figure D2. Setup of Transformer for High Voltage Full Wave Surge Test onto Secondary Winding.

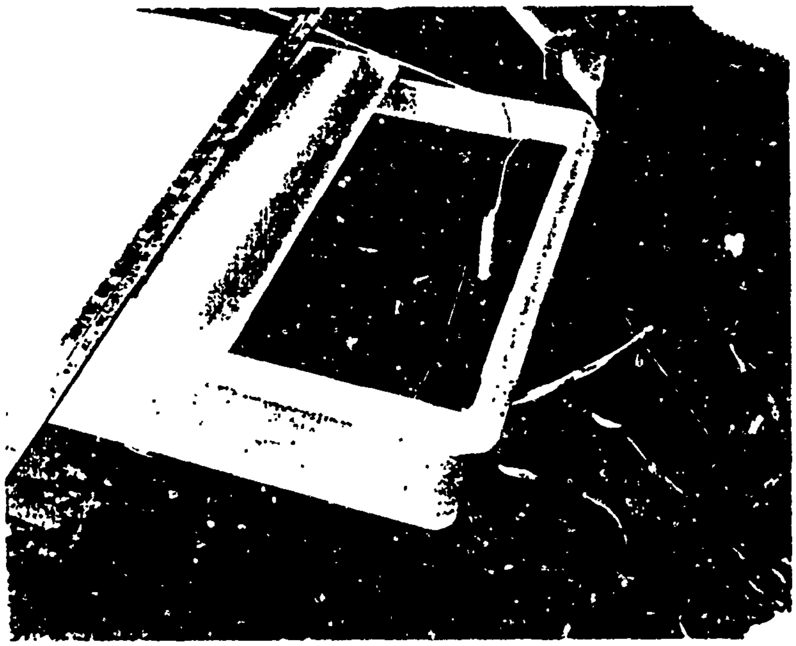
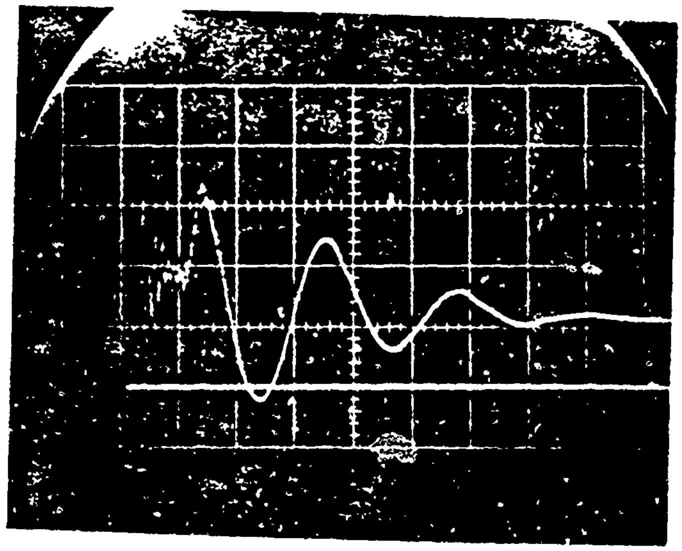


Figure D3. Picture of Flash Due to 210 KV Surge Pulse Onto Secondary Winding.

Phase 2 of the testing is covered on test sheets 3-10. Testing of the primary to secondary isolation began at a voltage of approximately 10 KV and increased to a peak of approximately 56 KV. Figure 4a and 4b shows an oscillogram and picture taken when a test apparatus capacitor blew during test number 4.

TABLE DI
Tabulation of Tests and Summary of Results

Test Configuration	Test Number	Waveform Peak KV	Full	Chop	Remarks
Secondary High-Secondary Low	1	210	x		Breakdown 1st shot
	2	210	x		Waveform check
Primary to Secondary	3	10	x		
	4	15	x		Lost capacitor on Marx
		(31)	x		Corrected & continued (Fig. 4a)
	5	30	x		1 of 2 (2nd during chop test).
	6	37.5	x		Arc to Bucket (Fig. 4b)
	7	48	x		
	8	56	x		
	9	56		x	Held for ~1.5μs
	10	64		x	Held for ~2.4μs
Primary High-Primary Low	11	12	x		Applied full waveform
	12	12	x		Chopped signal recorded
	13	12	x		Chopped signal recorded
	14	6	x		Signal still chopped
	15	6	x		
	16	28	x		Marx did not fire
	17	28	x		Chopped-carbon found in oil
	18	31	x		Shows applied waveform (Fig. not shown)



FigureD4a. Waveform applied to Transformer When Capacitor Blew causing a 31 KV Peak on Oscillation.

FigureD4b. Arc to Pail

Phase 3 was a lower voltage also, 6 KV - 31 KV. The primary high to low as impulse tested with a full wave (see Figure D5).

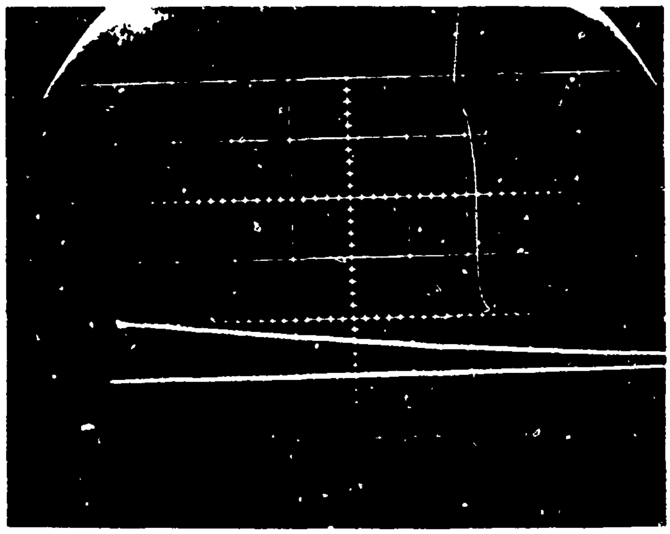


Figure D5. Full Waveform Used in Testing of Phase 3.

Recommendations

The test procedure specified appears to be inadequate for a test object of the type tested. It is recommended that the procedure be reviewed prior to implementation and modifying it as necessary to cover the specific test item. Alternatively, components which must pass the test procedure be configured differently than the item tested.

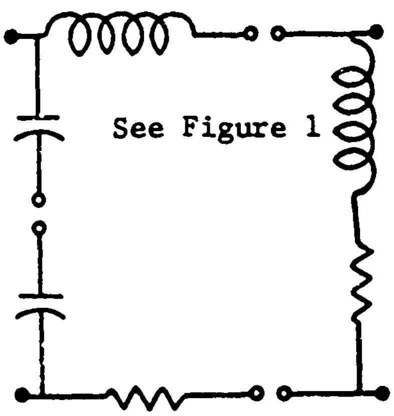
John G. Schneider

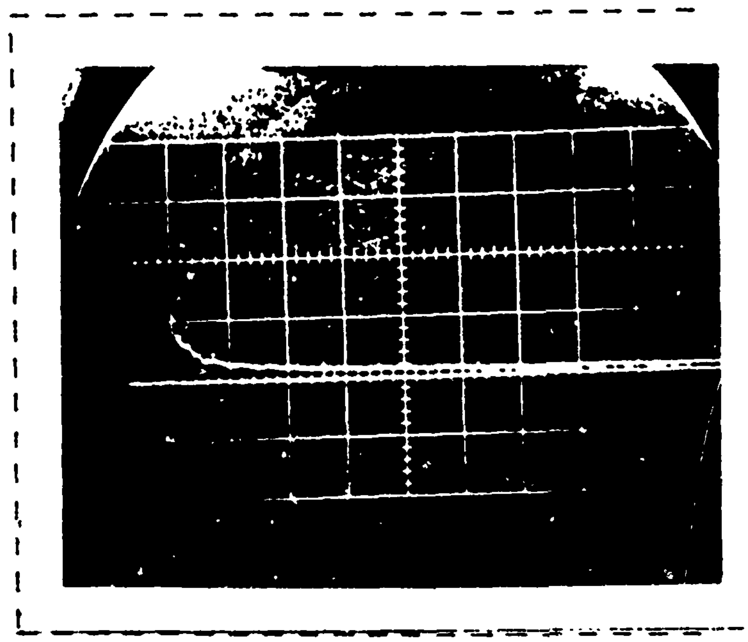
John G. Schneider
High Voltage Test Engineer

T/SSI TEST LOG

Test No. 1 Task ______ Date 3/18/81

Test Item Boeing Transformer



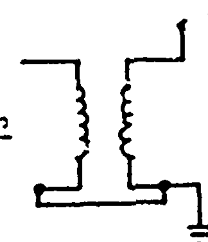


V_c = 17KV C_t = 46 nF

V_p = 210KV L_t = ____

I_p = ____ R_d = 180

R_L = 840



Scale Factors

f/o	1/
f/o atten	100
atten	5
V_D	600

Vert. 20 µV /Div.

Horiz. 2 µs /Div.

Remarks First shot did not fire at 16 KV charge. Charged to 17KV and reshot - held for an instant then fired - transformer broke down and showed at chopped wave. Tested secondary - high side to output & lowgrd'd. output voltage through resistors - 14 of 17 resistors

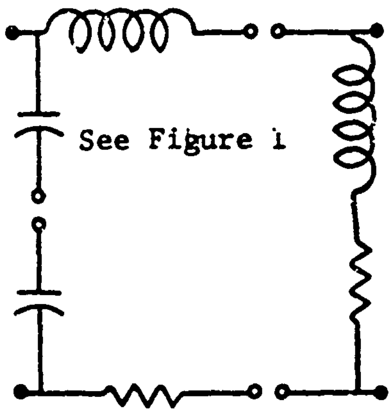
Instrumentation Tektronix 555/preamp Type L

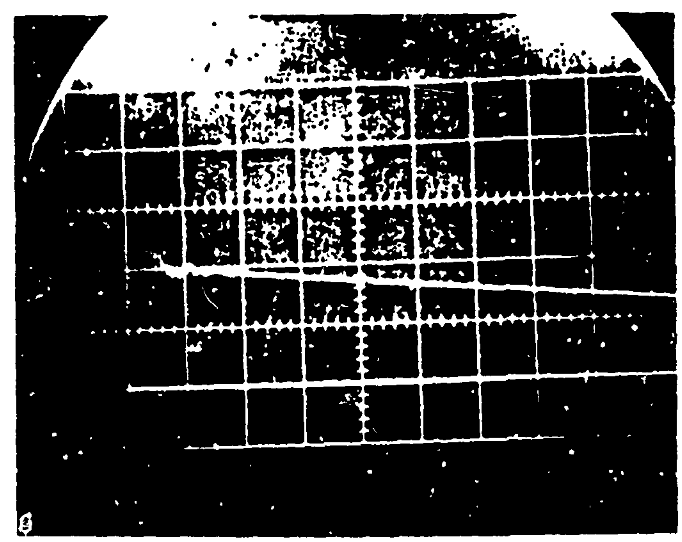
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 2 Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c =	20KV	C_t =	45nF
V_p =	210KV	L_t =	
I_p =		R_d =	180
		R_L =	840

Scale Factors

f/o	17
f/o atten	100
atten	5
V_D	600

Vert. 102 KV /Div.

Horiz. 2 μs /Div.

Remarks A waveform picture so we could verify that we tested with the correct waveform.

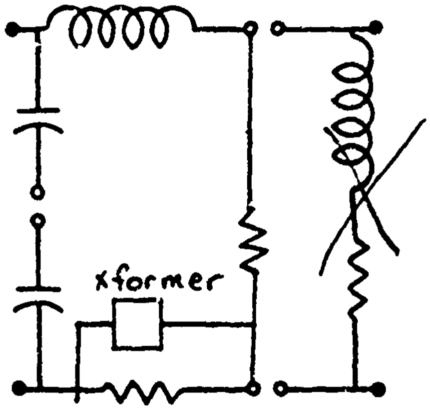
Instrumentation Tektronix 555/preamp Type L

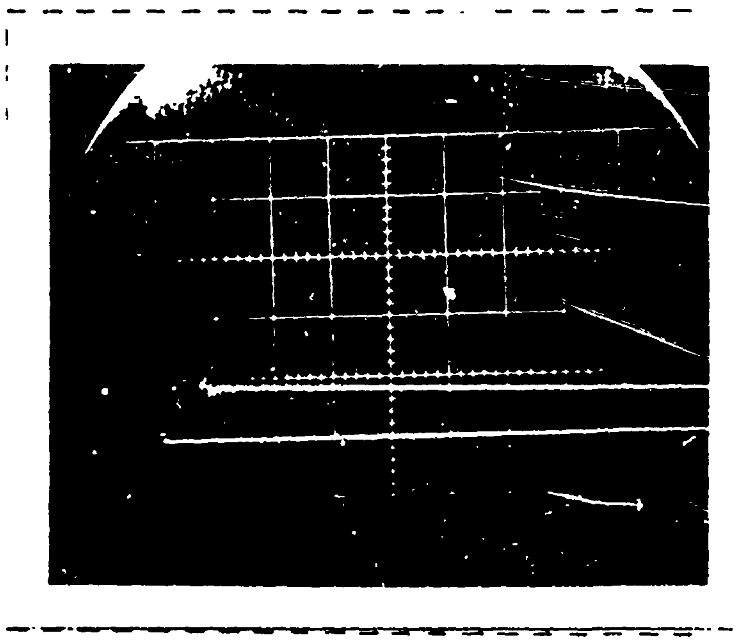
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 3 Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 20KV C_t = 46nF

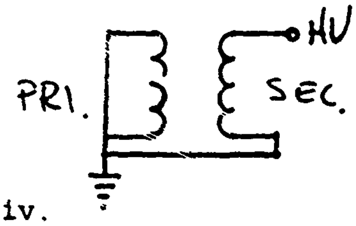
V_p = 10KV L_t = ______

I_p = ______ R_d = 1740

R_L = 60

Scale Factors

V_D	600
atten	50
f/o	17



Vert. 20 mV /Div.

Horiz. 2 μs /Div.

Remarks Waveform of voltage applied secondary to primary - with primary grd'd. 10.2 KV/div

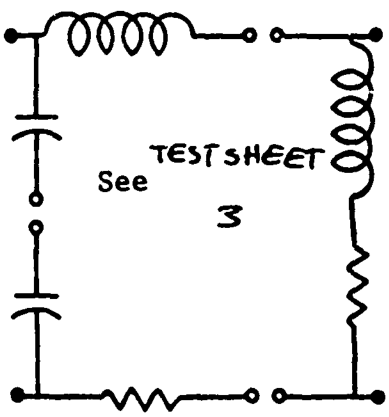
Instrumentation Tektronix 555/preamp Type L

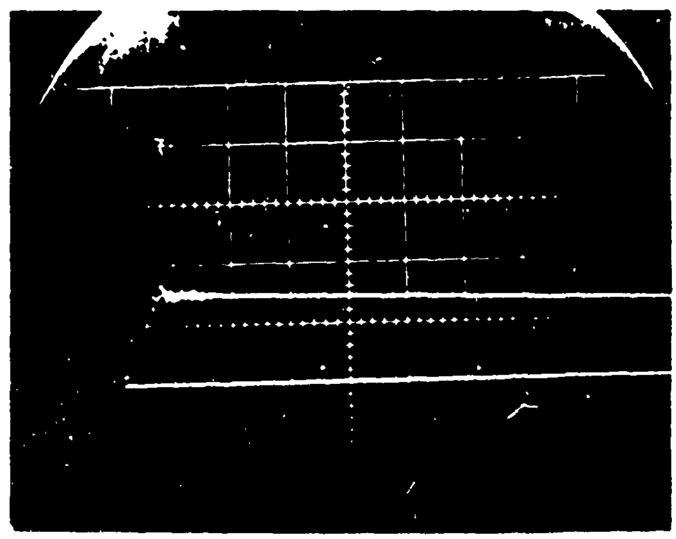
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 4 Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 25KV C_t = 70nF

V_p = 15KV L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

Vert. 10.2KV div /Div.

Horiz. 2 μs /Div.

Remarks 1st shot blew capacitor - rearrange with 10 caps

Scale the same - off 2 resistor of 30

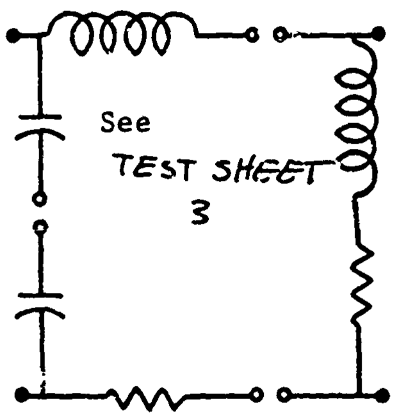
Instrumentation Tektronix 555/preamp Type L

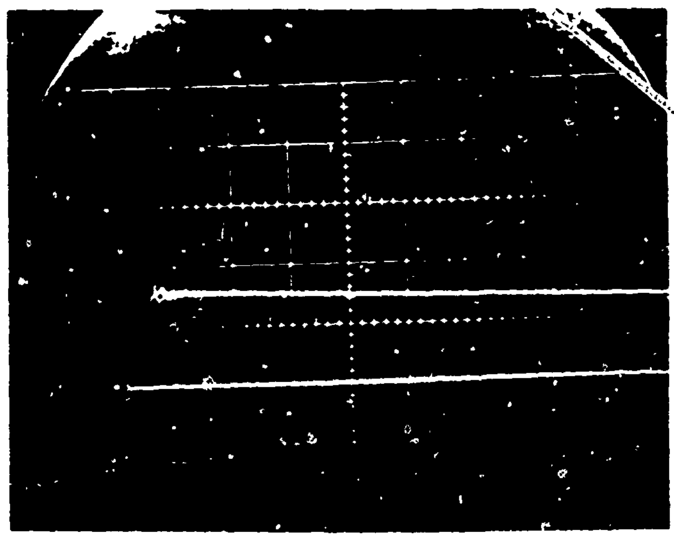
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 5 . Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 25KV C_t = 70nF

V_p = 30KV L_t = ____

I_p = ____ R_d = ____

R_L = ____

Scale Factors

V_D	600
atten	100
f/o	17

Vert. 20 mV /Div.

Horiz. 2 μs /Div. Approx.20KV/div

Remarks Using 4 resistors of 30

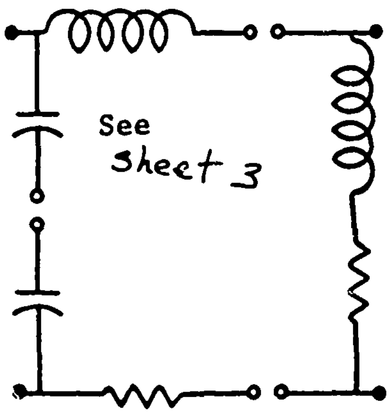
Instrumentation Tektronix 555/preamp Type L

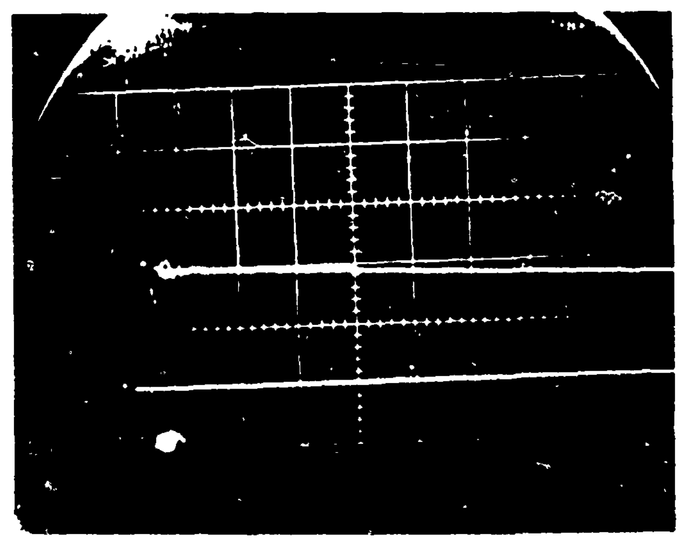
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 6 . Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 25KV C_t = ____

V_p = 37.5KV L_t = ____

I_p = ____ R_d = ____

R_L = ____

Scale Factors

V_L	600
atten	100
f/o	1.7

Vert. 20 mV /Div.

Horiz. 2 µs /Div.

Remarks 5 of 30 resistors

Something broke down. Arc to bucket - .11 µshot (B)

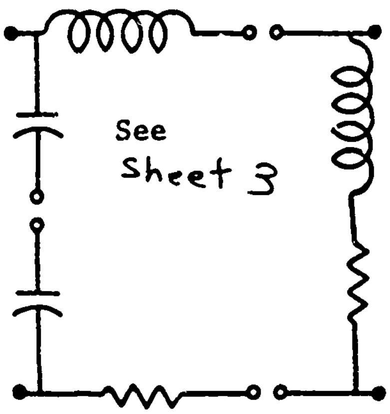
Instrumentation Tektronix 555/preamp Type L

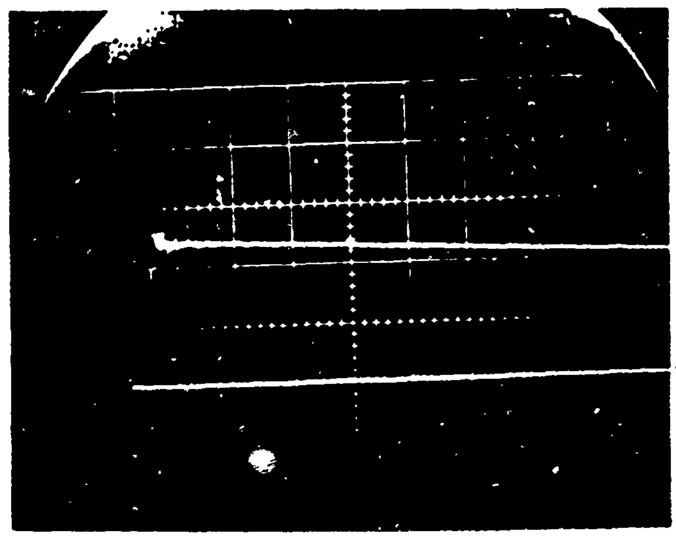
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 7 Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 25KV C_t = ____

V_p = 48KV L_t = ____

I_p = ____ R_d = ____

R_L = ____

Scale Factors

V_D	600	
atten	100	
f/o	17	Vert. 20 mV /Div.
		Horiz. 2 μs /Div.

Remarks 6 of 30 resistors

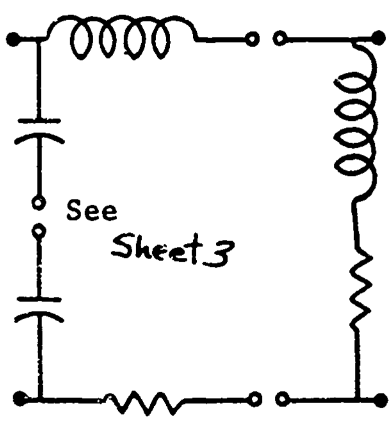
Instrumentation Tektronix 555/preamp Type L

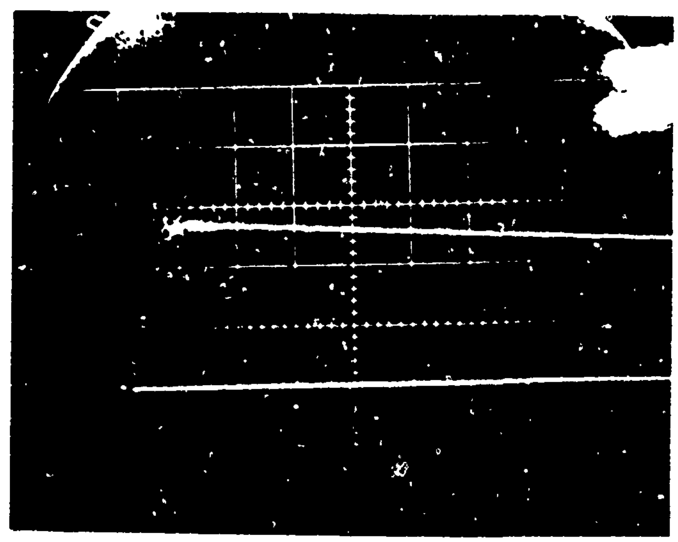
Test Supervisor J. Schneider   Contract F95731

T/SSI TEST LOG

Test No. 8 Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 28KV C_t = ______

V_p = 56KV L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

V_D	600
atten	100
f/o	17

Vert. 20 mV /Div.

Horiz. 2 μs /Div.

Remarks Maximum rating of transformer

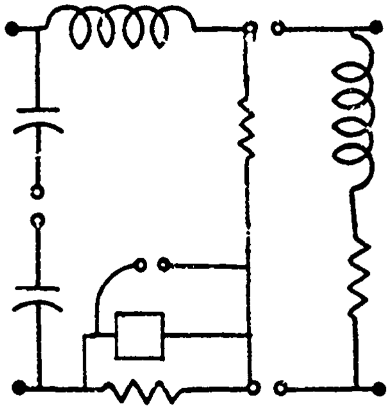
Instrumentation Tektronix 555/preamp Type L

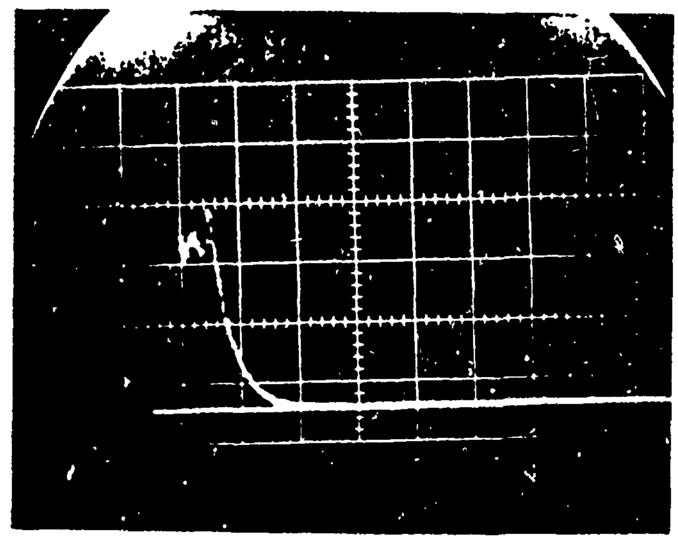
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 9 Task ________ Date 3/18/81

Test Item Boeing Transformer





V_c= 24KV C_t = ____

V_p= ____ L_t = ____

I_p= ____ R_d= ____

R_L= ____

Scale Factors

V_D	600
atten	100
f/o	17

Vert. 20 mV /Div.

Horiz. 2 μs /Div.

Remarks 7/30 resistor (20.4 KV/div)

Test called for minimum of 1.5 μs before chop.

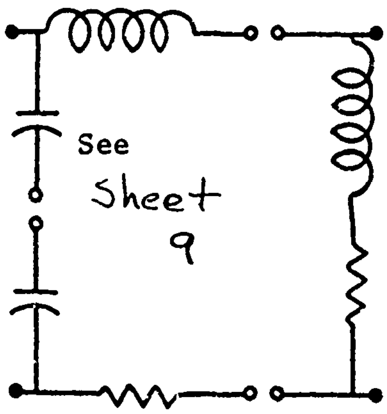
Instrumentation Tektronix 555/preamp Type L

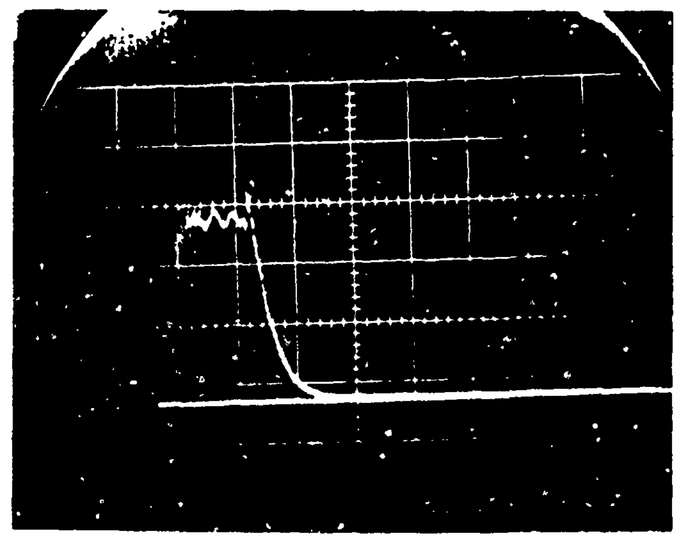
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 10 Task ______ Date 3/18/81

Test Item Boeing Transformer





V_c = 27 5KV C_t = ______

V_p = 60KV L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

V_D	600
atten	100
f/o	17

Vert. 20 mV /Div.

Horiz. 2 μs /Div.

Remarks 7/30 resistors

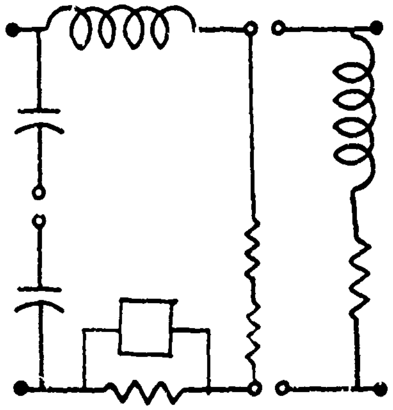
Instrumentation Tektronix 555/preamp Type L

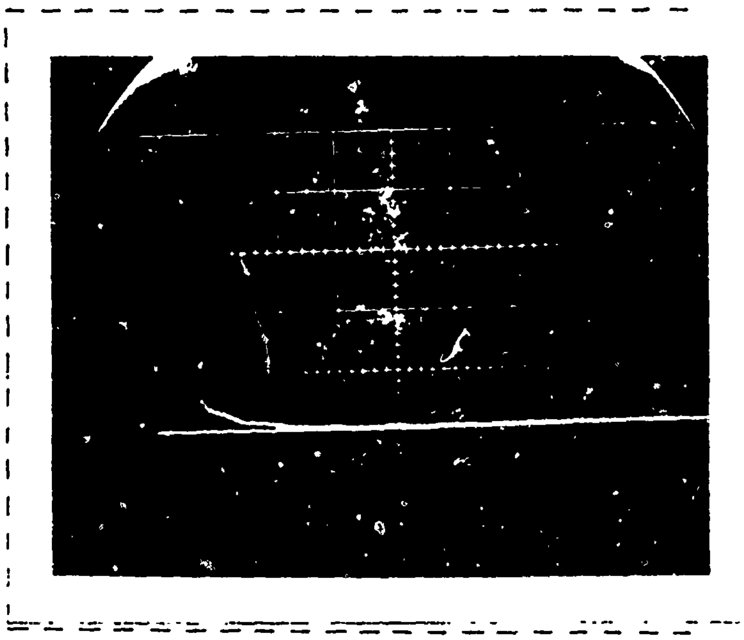
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 11,12,13 Task ______ Date 3/19/81

Test Item Boeing Transformer



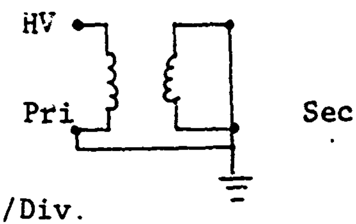


V_c = 26KV C_t = 70nF

V_p = 12KV L_t = ______

I_p = ______ R_d = 1200

R_L = 120



Scale Factors

V_D	600
atten	100
f/o	10

Vert. 20 mV /Div.

Horiz. 2 μs /Div.

Remarks 2 of 22 resistors - repeated since #1 showed chopped wave. #3 of same - to insure it was hooked properly and the bucket was not affecting results.

3 shots all showed the same results.

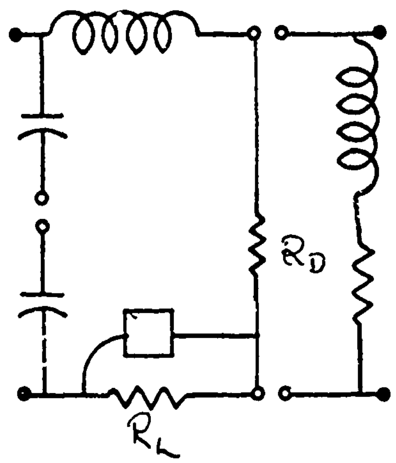
Instrumentation Tektronix 555/preamp Type L

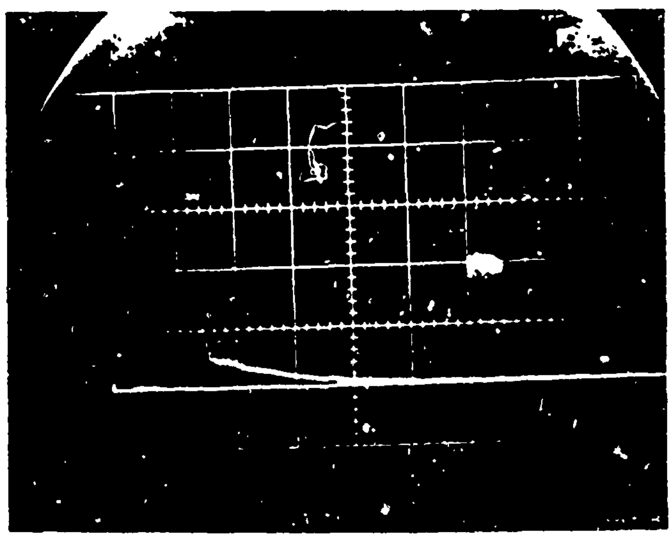
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 14,15 Task ______ Date 3/19/81

Test Item Boeing Transformer





V_c = 26 C_t = 70

V_p = 6KV L_t = ______

I_p = ______ R_d = 1260

R_L = 60

Scale Factors

V_D	600
atten	50
f/o	10

Vert. 20 mV /Div.

Horiz. 2μs /Div.

Remarks Low voltage, a slight change - longer tail-missed #14 - no oscillogram.
1 of 22 resistors on the output

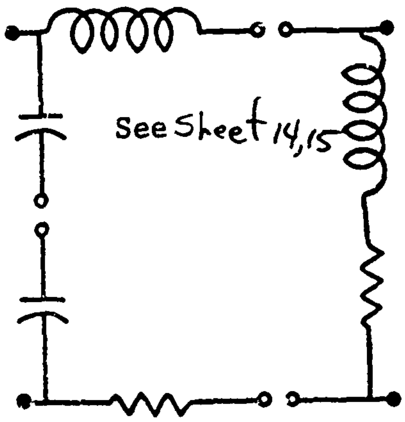
Instrumentation Tektronix 555/preamp Type L

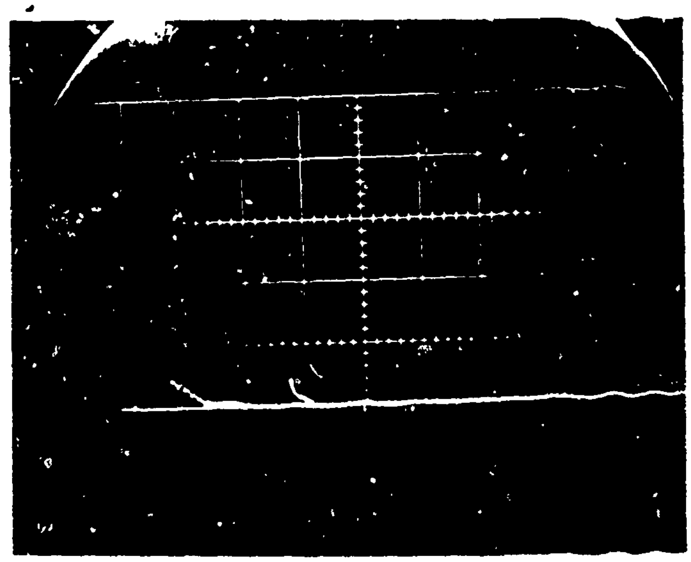
Test Supervisor J. Schneider Contract F95731

T/SSI TEST LOG

Test No. 16,17,18 Task ______ Date 3/19/81

Test Item Boeing Transformer





V_c = 35KV C_t = 70

V_p = 28KV L_t = ____

I_p = ____ R_d = 1200

R_L = 120

Scale Factors

V_D	600
atten	100
f/o	10

Vert. 20 mV /Div.

Horiz. 2 μs /Div.

Remarks 1st time Marx didn't erect.
#17 is 35 KV charge - no waveform was obtained (?)
But some residue was found on the transformer oil. (carbon floating)
#18 waveform app[illegible]ed during 17.

Instrumentation Tektronix 555/preamp Type L

Test Supervisor J. Schneider Contract F95731

APPENDIX D

SECTION 2

SURGE TEST DATA OF A PART
OF ALTERNATOR COILS
ON A TEST JIG

CTM-146-81-72B F33615-79-C-2067

TECHNOLOGY/SCIENTIFIC SERVICES, INC.
A SUBSIDIARY OF TECHNOLOGY INCORPORATED
P. O. Box 3065, Overlook Branch, Dayton, Ohio 45431
Tel. (513) 426-2405

May 11, 1981

TO: Boeing Aerospace Company
P.O. Box 3999 Mail Stop 8K-75
Seattle, WA 98124

SUBJECT: APPENDIX D - Additional Testing on Generator Coil Test Jig

Background. The generator coil test jig was part of the original test plan but was not available during the time frame allotted.

The jig contained two phases of the generator. An impulse voltage waveform was applied phase-to-phase with a piece of dielectric in between the phase wire windings. The impulse voltage amplitudes were increased at approximately 20 KV per step. The original test shot was made at 40 KV.

Test Results. Attached at the end of this report are the original data sheets from the tests. The first shot broke down around the plexiglas insulation. The new epoxy and laminations to be used in the generator did not fail.

The oscillogram on data sheet #1 showed a chopped waveform as expected when an arc shorts out the load impedance. The plexiglas piece was cleared and moved to a better location. Data sheet #2 shows the full waveform applied to the test jig with a 1 x 50μs waveform.

However, starting with test #3, arc tracking began on either the test piece of epoxy or the plexiglas pieces tried. Finally the test voltage was backed off to 50 KV peak and a full waveform was recorded (see sheet #14). Small high frequency bursts on the waveform indicate corona, meaning close to breakdown.

The epoxy piece was removed from the generator coil and placed on a spark gap stand and further testing at higher voltage was performed.

Test sheet #15 shows full waveform at 65 KV peak and sheet #16 shows the capped waveform at 90 KV peak. Test sheet #17 is at 80 KV peak and again showing a chopped waveform. Figure D6 shows the arc tracking around, but not puncturing, the epoxy piece.

Figure D6. Arc Tracking Around the Epoxy Test Piece. (Shot #17).

The generator coil test jig was reattached to the Marx generator and phase-to-phase voltage hold-off with no added insulation was tested. Shot #18 showed a full wave with approximately 30 KV hold-off. Shot #19 at approximately 35 KV peak chopped, indicating the limiting value in air at approximately 30 KV.

The second day of testing was to evaluate a second piece of epoxy insulation. One piece of epoxy insulation between each crossing of the two phases. The first firing held at 45 KV; at 50 KV the waveform chopped (see test sheet 2a) and Figure D7 shows the arc tracking the insulation.

Before the next shot some Kapton tape was added to deter tracking around the edges of the epoxy. Test #3a shows a somewhat higher hold-off at 56 KV but test #4a shows the waveform chopped at approximately 61 KV, the upper limit of testing on the generator coil test jig.

The second epoxy piece was moved to the spark gap test stand and test #6a through #10a show an increase in hold-off voltage to 90 KV. Test sheet #11a shows the waveform chopped at approximately 100 KV. Figure D8 shows that the arc tracked around the epoxy piece and did not puncture.

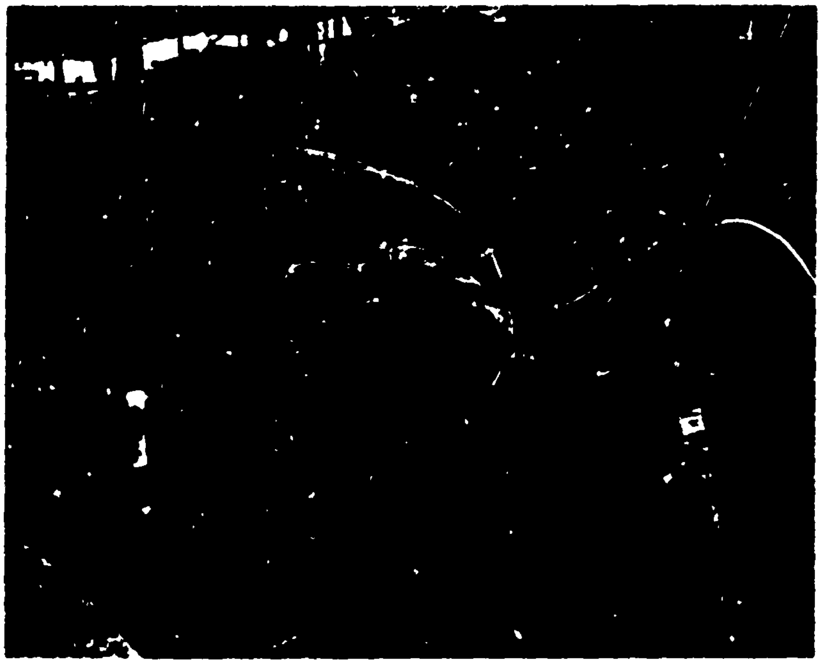


Figure D7. Arc Tracking Around Epoxy Insulation with Epoxy Piece Between Both Coil Crossings. (Shot #2a).

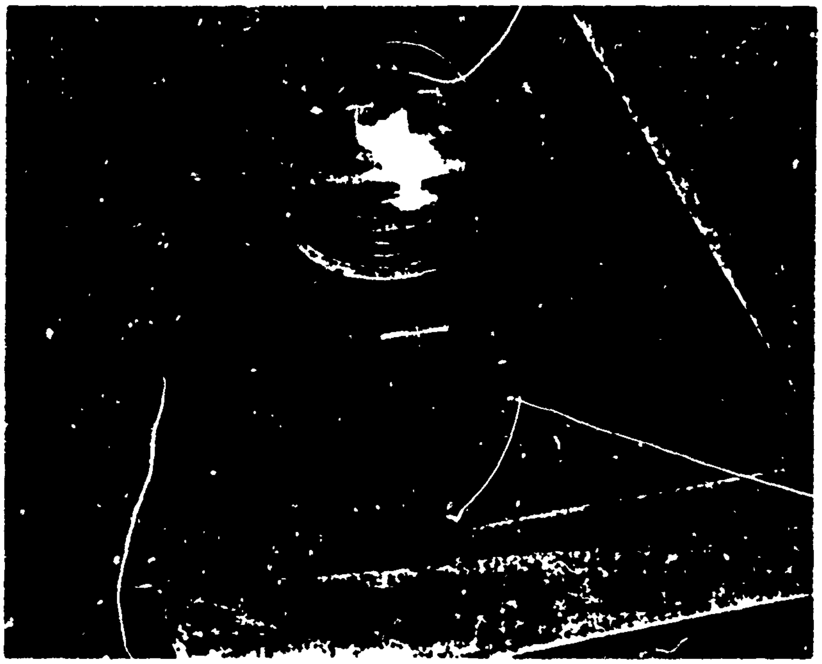


Figure D8. Arc Tracking Second Epoxy Piece (Shot #11a).

Comments. Many shots we· taken during the test which proved to be unnecessary. Testing ‿ small piece of insulation in the generator coil test jig is not a justifiable way of evaluating the insulation. All insulation material traces to a certain extent, thus the insulator cannot be accurately tested unless two conditions are met:

1. Enough material must be used so that the tracking does not occur prior to puncture,

2. If tracking is to be tested as well as puncture in a test set up, then an accurate representation of the insulation piece must be used.

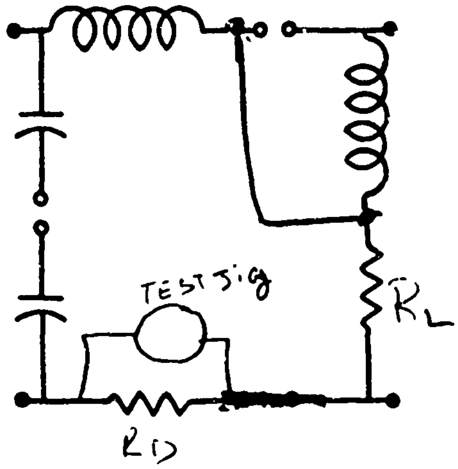
John G. Schneider
High Voltage Engineer

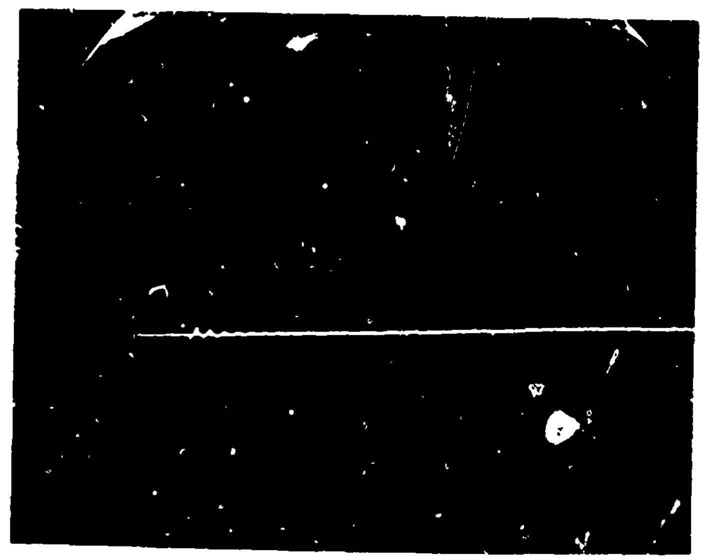
skw

T/SSI TEST LOG

Test No. #1 Task ______ Date 4/27/81

Test Item Generator Coil Test Jig's





V_c = 200kV C_t = 70nfd

V_p = 40kV L_t = 3

I_p = N/A R_d = 300

R_L = 1080

Scale Factors

10	10
~~4000RD~~	~~1600~~
Attn	500

Vert. 60.0 kV /Div.

Horiz. 5 µs /Div.

Remarks 1st short of Gen. Coil.

Arc at coil windings - not at point of interest

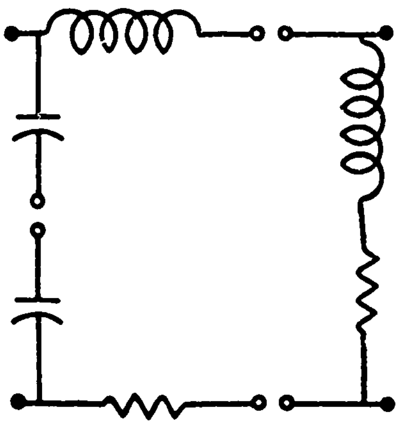
Instrumentation 555 / Type L

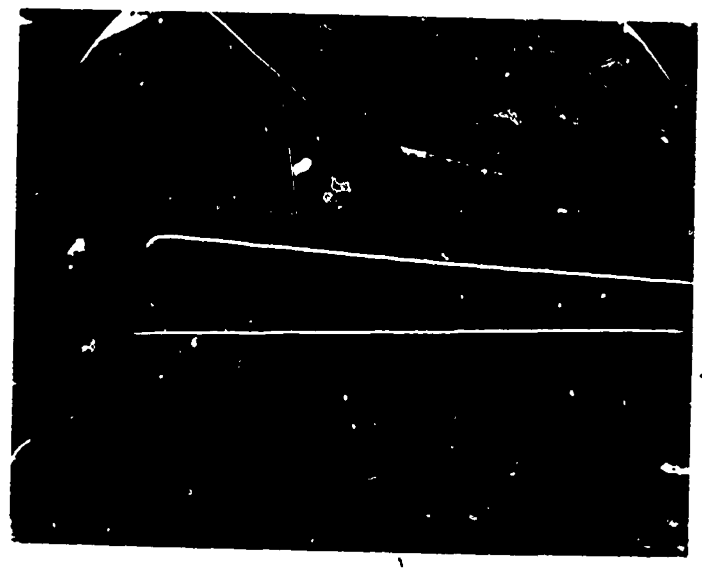
Test Supervisor JS Contract Boeing

T/SSI TEST LOG

Test No. #2 Task________ Date 4/21/81

Test Item________





V_c = [illegible] C_t = [illegible]

V_p = [illegible] L_t = ____

I_p = [illegible] R_d = [illegible]

R_L = [illegible]

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	250

Vert. 30 [illegible] /Div.
Horiz. [illegible] [illegible] /Div.

Remarks________

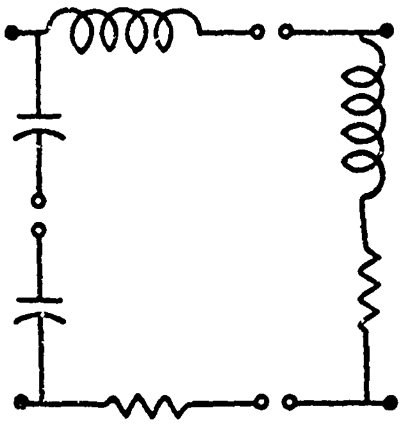
Instrumentation________

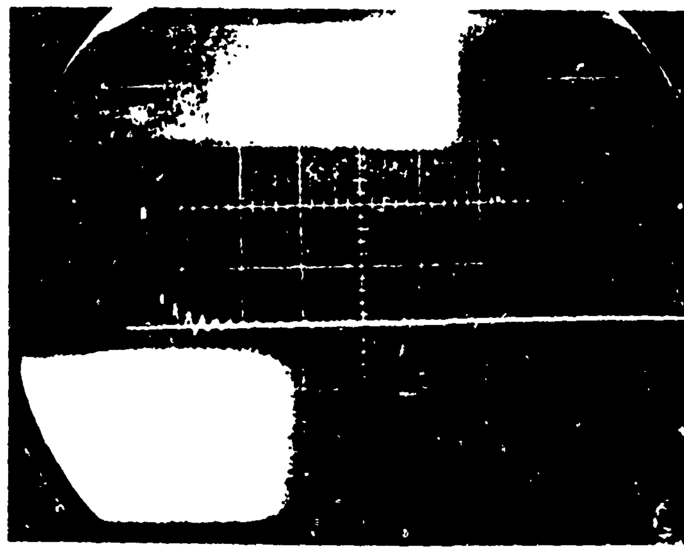
Test Supervisor________ Contract________

T/SSI TEST LOG

Test No. 3 Task ______ Date 4/27/81

Test Item ______





V_c = 210 KV C_t = 72 nfd

V_p = 60 KV L_t = ____

I_p = N/A R_d = 460

R_L = 960

Scale Factors

1/0	710
RD	600
1771	250

Vert. ~~80~~ 30 KV /Div.

Horiz. 5 μs /Div.

Remarks TRACKS AROUND epoxy TEST JIG piece.

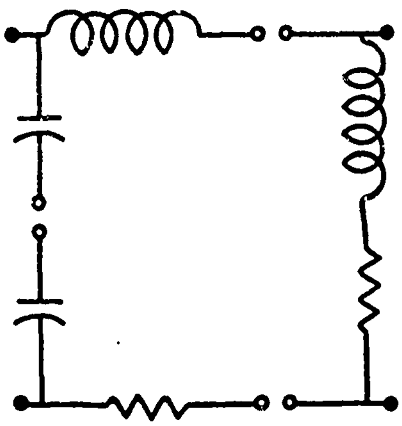
Instrumentation ______

Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 4 Task ______ Date · - · 71

Test Item ______



V_c = 210 kV C_t = 20 nfd

V_p = 6 kV L_t = —

I_p = N/A R_d = 76Ω

R_L = 96Ω

Scale Factors

r/s	110
R D	600
...	250

Vert. ~~25~~ 30 kV /Div.

Horiz. 5 μsec /Div.

Remarks FLEXIGLASS TRACKED

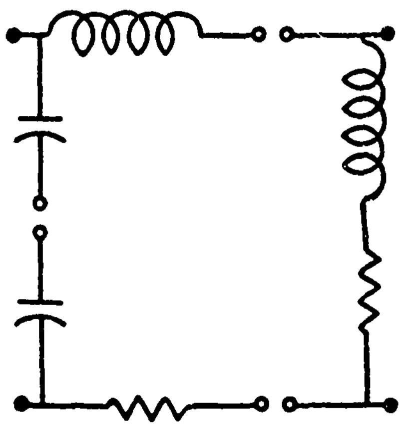
Instrumentation ______

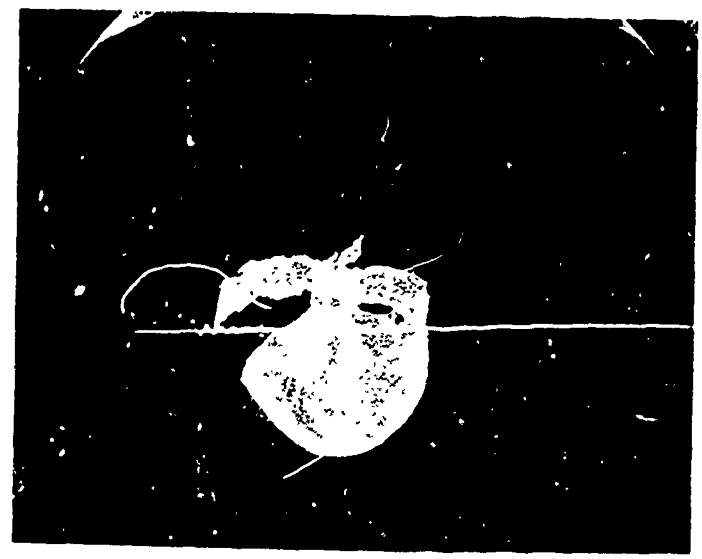
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 5 Task ______ Date 9/22/81

Test Item ______





V_c = 200 kV C_t = 70 nfd

V_p = 60 kV L_t = –

I_p = N/A R_d = 440

R_L = 960

Scale Factors

1/1	x10
RD	600
ATTN	250

Vert. ~~24~~ 30 KV /Div.

Horiz. 5 μSEC /Div.

Remarks TRACKED AROUND TEST SPECIMEN

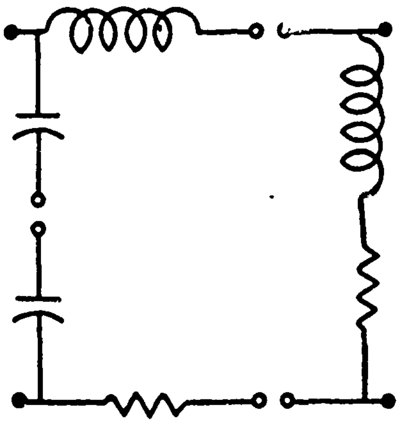
Instrumentation ______

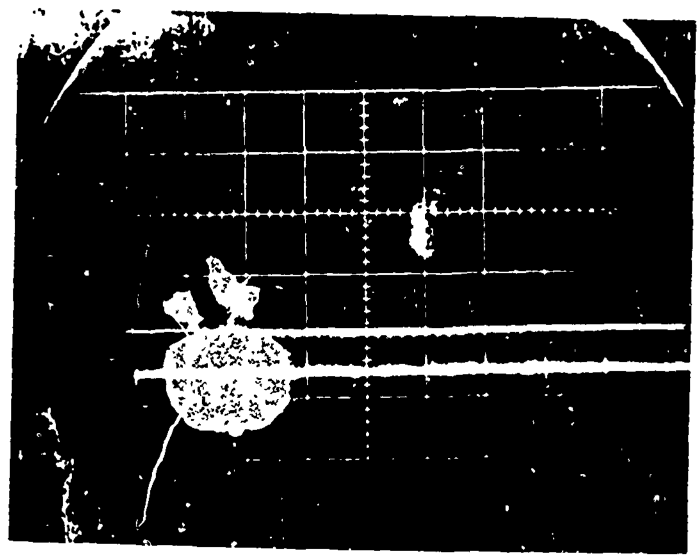
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 6 Task ________ Date 4/27/81

Test Item ________





V_c = 210 kV C_t = 70 nfd

V_p = 60 kV L_t = ____

I_p = [illegible] R_d = 440

R_L = 960

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	2.6

Vert. 30 kV /Div.

Horiz. 5 μsec /Div.

Remarks ________

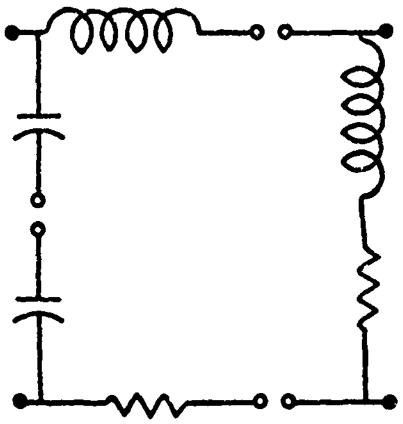
Instrumentation ________

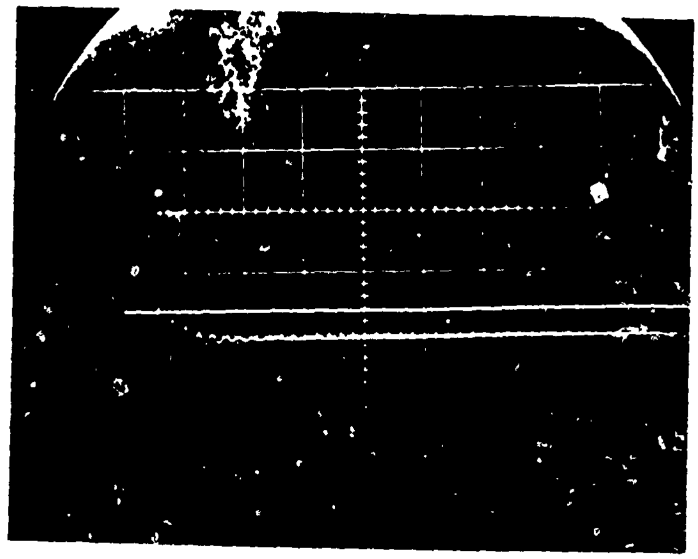
Test Supervisor ________ Contract ________

T/SSI TEST LOG

Test No. 7 Task ______ Date 4/2[illegible]/81

Test Item ______





V_c = [illegible] C_t = 70 nfd

V_p = 60 kV L_t = ____

I_p = [illegible] R_d = 440

R_L = 960

Scale Factors

F/S	10
FD	600
ATTN	250

Vert. 24 KV /Div.

Horiz. 5 μsec/Div.

Remarks STILL TRACKING [illegible]

[illegible]

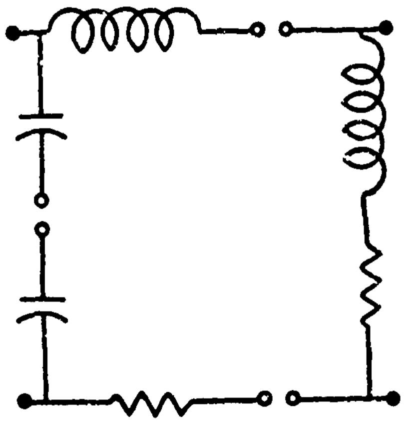
Instrumentation ______

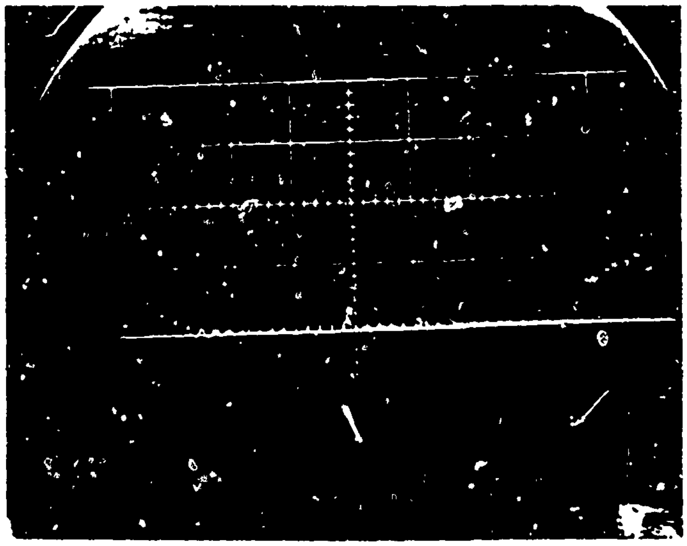
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 8 Task ______ Date 4/2-/81

Test Item ______





V_c= 210 k.v. C_t = 10.nfd

V_p= 60 kv L_t = ____

I_p= N/A R_d= 440

R_L= 960

Scale Factors

r/0	10
kv	600
[illegible]	250

Vert. 50 kV /Div.

Horiz. 5 μSEC /Div.

Remarks STILL TRACKING

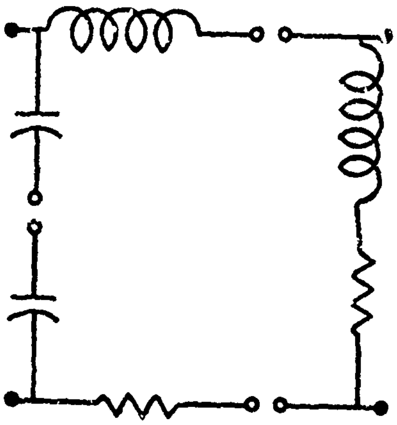
Instrumentation ______

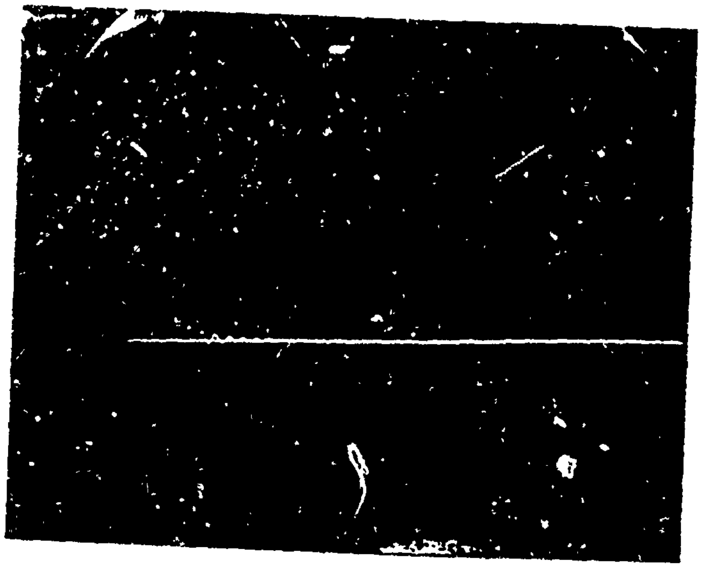
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 7 Task ________ Date ________

Test Item ________





V_c = 210 kV C_t = 70 nfd

V_p = 60 kV L_t = ____

I_p = N/A R_d = 440

R_L = 960

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μsec /Div.

Remarks STILL ARCING

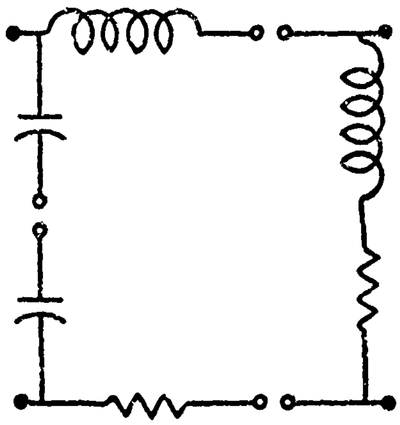
Instrumentation ________

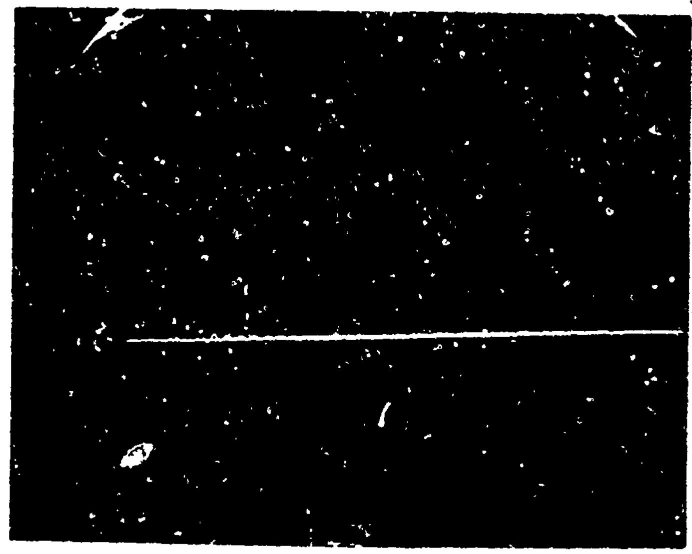
Test Supervisor ________ Contract ________

T/SSI TEST LOG

Test No. 10 Task ______ Date [illegible]

Test Item ______





V_c = ~~240~~ 210 kV C_t = 70 [illegible]

V_p = 60 [illegible] L_t = ____

I_p = [illegible] R_d = 440

R_L = 960

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μSEC /Div.

Remarks Tracking

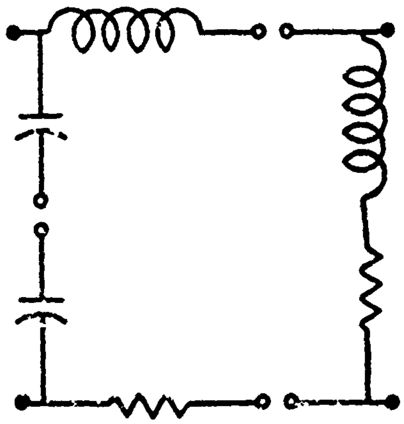
Instrumentation ______

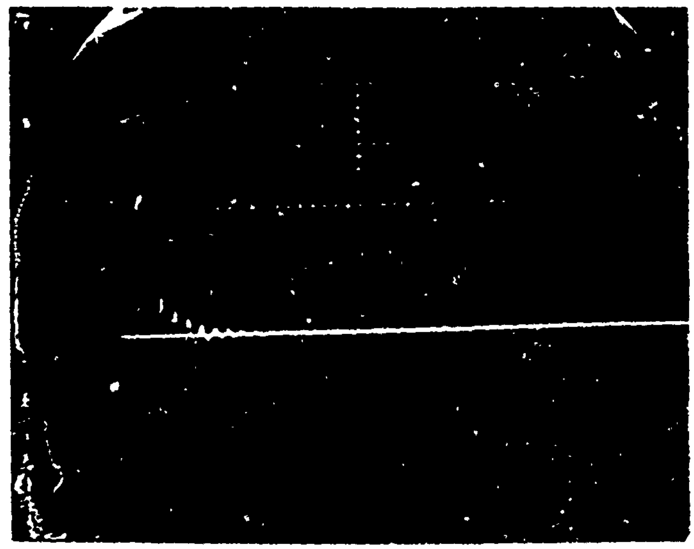
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 11 Task ______ Date [illegible]

Test Item ______





V_c= 240[illegible] C_t =70 [illegible]
V_p= 60kV L_t = –
I_p= [illegible] R_d= 440
R_L= 960

Scale Factors

[illegible]	10
R[illegible]	600
[illegible]	250

Vert. 30 kV /Div.
Horiz. 5 μSEC /Div.

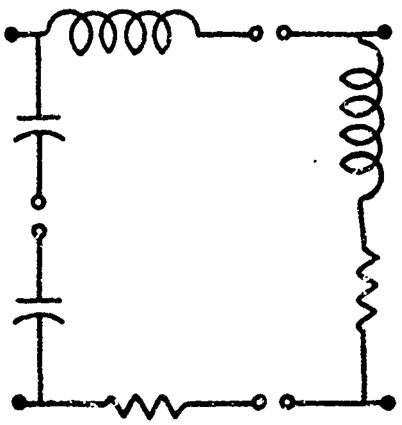
Remarks STILL TRACKING

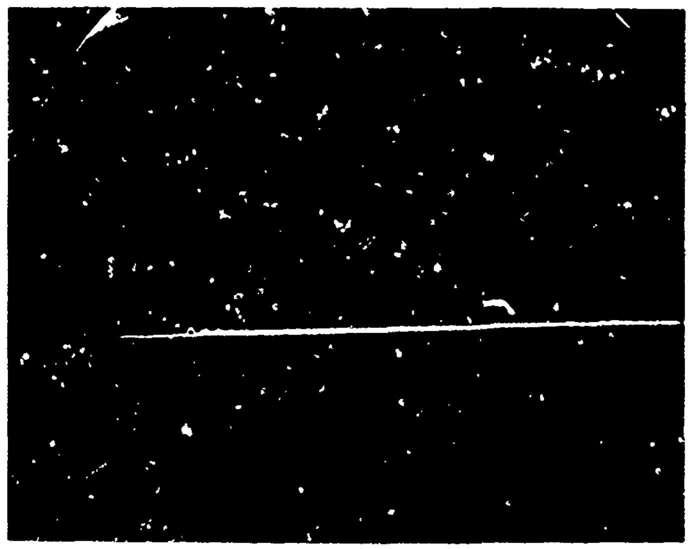
Instrumentation ______
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 12 Task ________ Date 4/ [illegible]

Test Item ________





V_c = 210 kV C_t = 70 nfd

V_p = 60 kV L_t = ____

I_p = [illegible] R_d = 440

R_L = 960

Scale Factors

C/U	10
[illegible]	600
[illegible]	250

Vert. 30 kV/Div.

Horiz. 5 μSEC/Div.

Remarks STILL TRACKING

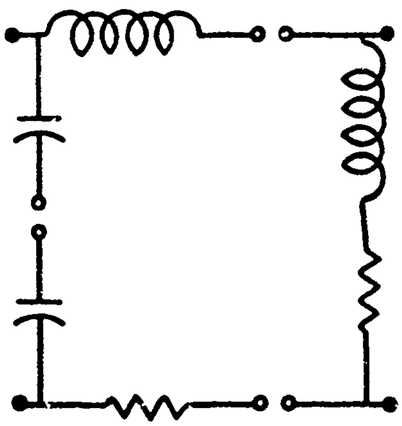
Instrumentation ________

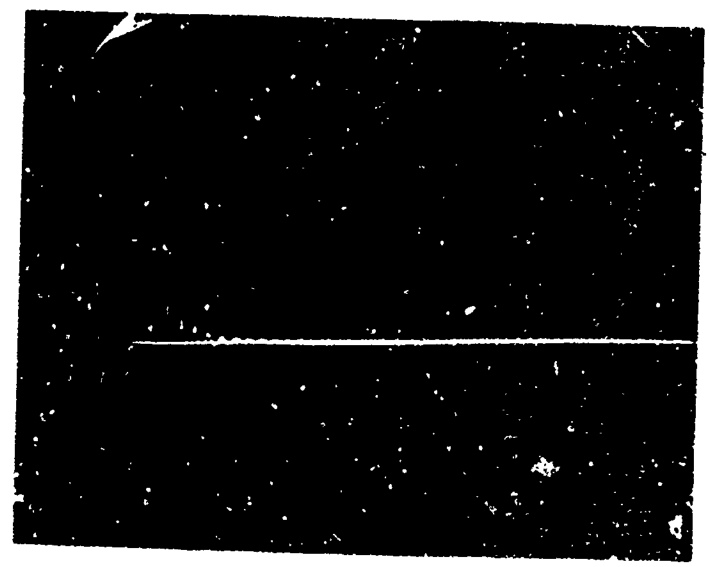
Test Supervisor ________ Contract ________

T/SSI TEST LOG

Test No. 13 Task ______ Date [illegible]

Test Item ______





V_c = 190 KV C_t = 70 nfd

V_p = 50 L_t = ____

I_p = [illegible] R_d = 440

R_L = 960

Scale Factors

F/10	10
[illegible]	600
[illegible]	250

Vert. 30 KV /Div.

Horiz. 5 µsec /Div.

Remarks STILL TRACKING

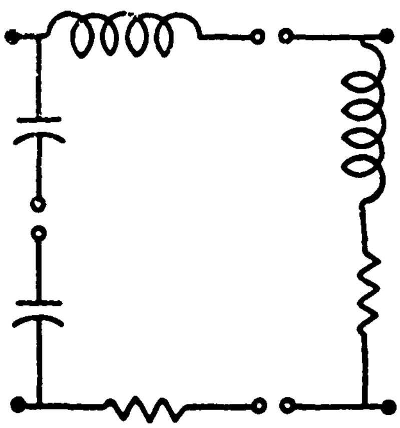
Instrumentation ______

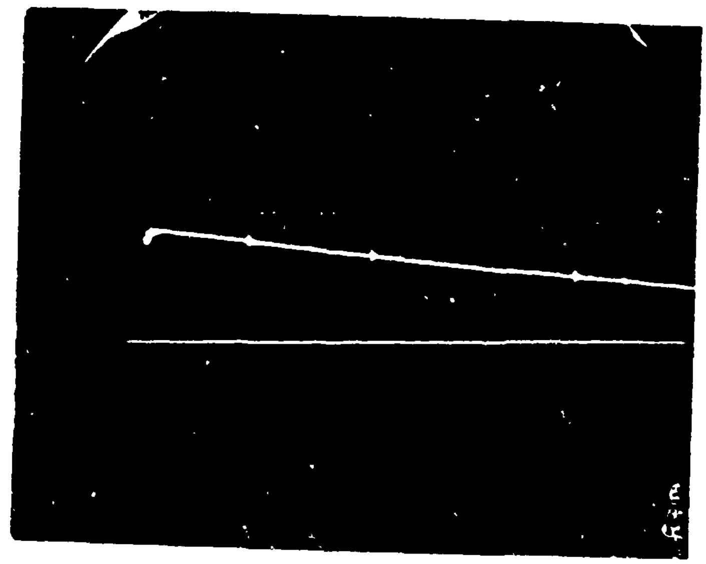
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 14 Task ____ Date 4 / ____

Test Item ____





V_c = 220 W C_t = 70 nfd

V_p = 50 kV L_t = ____

I_p = n/a R_d = 300

R_L = 1080

Scale Factors

1/10	10
60	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μsec /Div.

Remarks ok

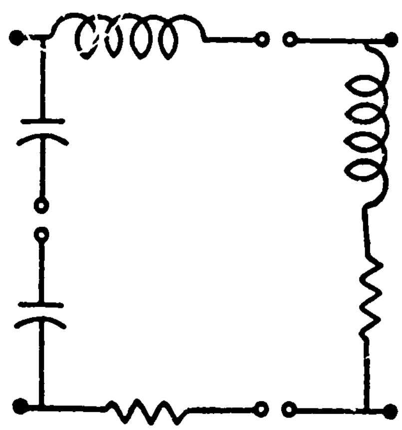
Instrumentation ____

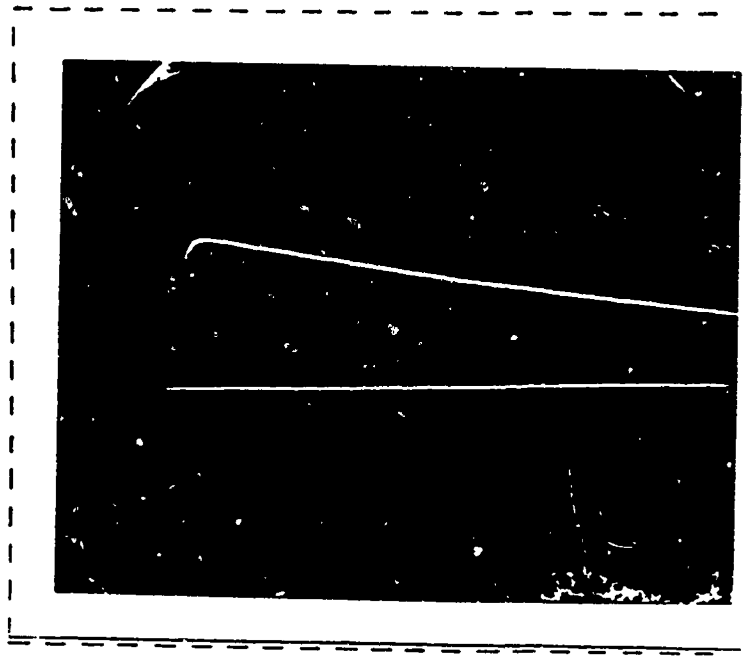
Test Supervisor ____ Contract ____

T/SSI TEST LOG

Test No. 15 Task ______ Date 7/2 [illegible]

Test Item ______





V_c = 210 kv C_t = 70 nfd

V_p = 65 L_t = ______

I_p = ______ R_d = 420

R_L = ______

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	250

Vert. 30 kv /Div.

Horiz. 6 μsec /Div.

Remarks USED VERY SMALL GAP - [illegible] from generator coil test jig to a spark gap for further testing.

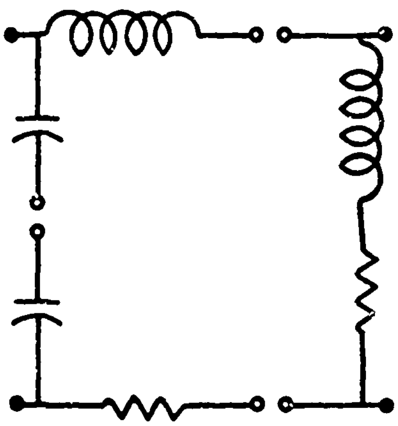
Instrumentation ______

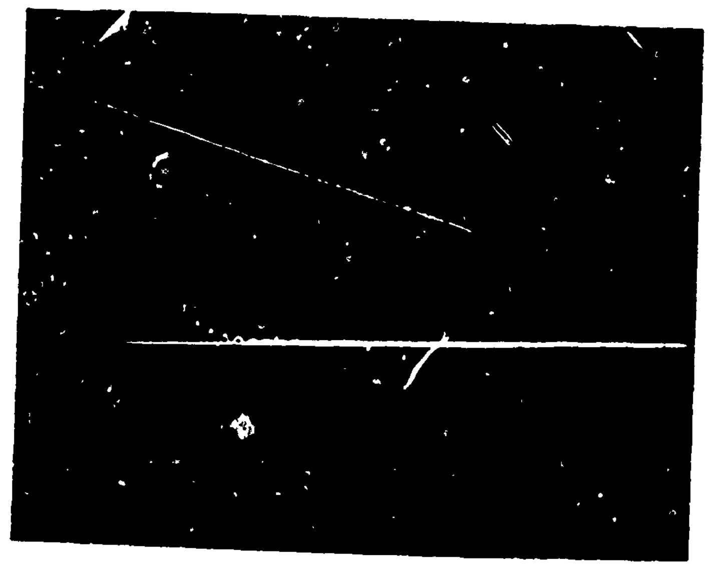
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 16 Task ______ Date [illegible]

Test Item ______





V_c= 200 kV	C_t =		
V_p= 90	L_t =		
I_p=	R_d= 690		
	R_L=		

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μsec /Div.

Remarks TRACKED

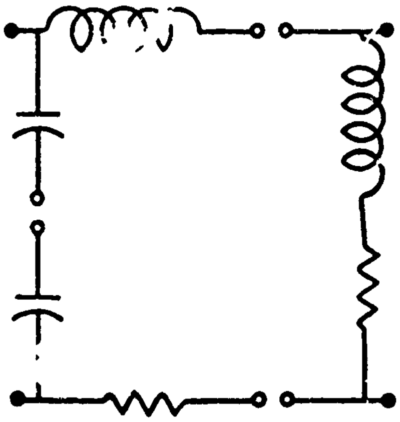
Instrumentation ______

Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 17 Task ________ Date [illegible]

Test Item ________



V_c = 170 C_t = ____

V_p = 80 L_t = ____

I_p = ____ R_d = 690

R_L = ____

Scale Factors

[illegible]	10
[illegible]	600
[illegible]	250

Vert. 30 KV /Div.

Horiz. 5 μSEC /Div.

Remarks TRACKED

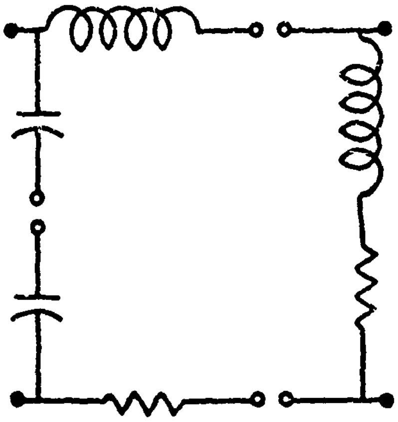
Instrumentation ________

Test Supervisor ________ Contract ________

T/SSI TEST LOG

Test No. 18 Task _____ Date [illegible]/81

Test Item _____



V_c = _____ C_t = _____

V_p = 26 KV L_t = _____

I_p = _____ R_d = 180

R_L = _____

Scale Factors

r/o	100
LD	600
[illegible]	250

Vert. 12 KV /Div.

Horiz. 5 μSEC /Div.

Remarks AIR GAP · GENERATOR COIL INSULATIONS, PHASE TO PHASE TEST

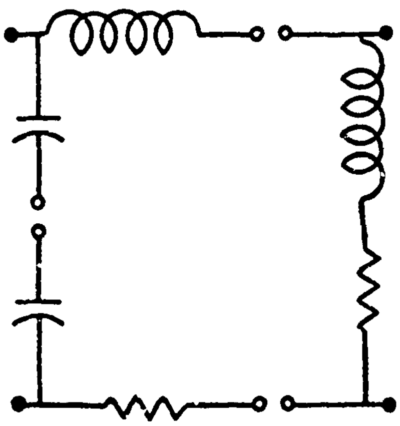
Instrumentation _____

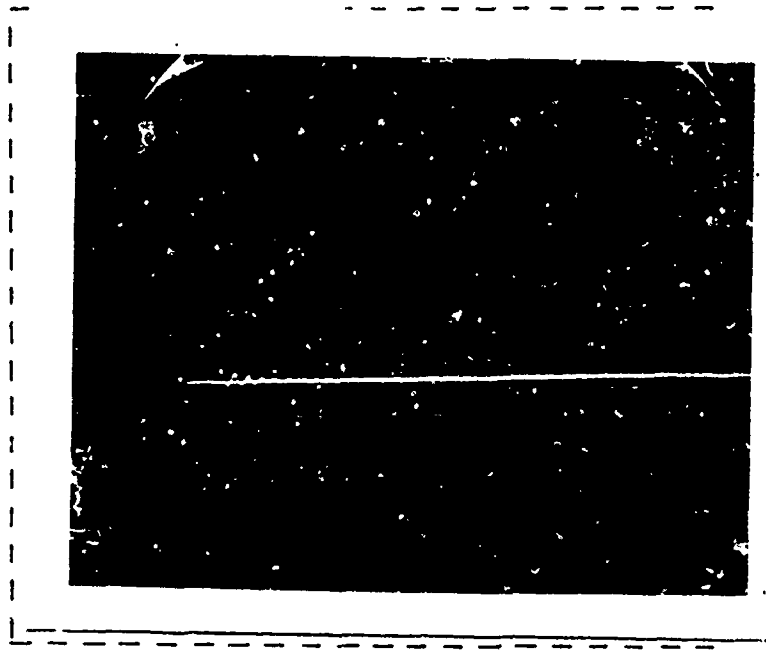
Test Supervisor _____ Contract _____

T/SSI TEST LOG

Test No. 19 Task ______ Date ______

Test Item ______





V_c= 260 C_t = ______

V_p= 40 L_t = ______

I_p= ______ R_d= 100

R_L= ______

Scale Factors

.10	10
.20	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μSec /Div.

Remarks FLASHOVER

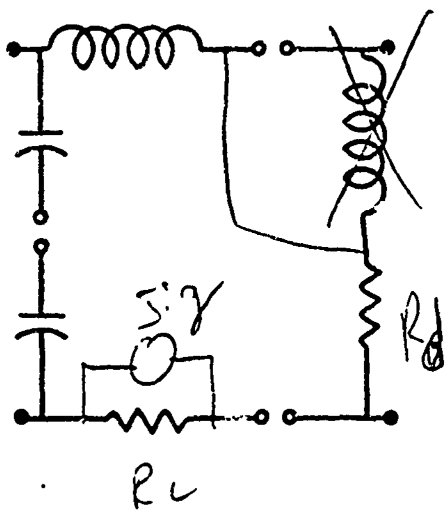
Instrumentation ______

Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 1a Task ______ Date [illegible]

Test Item ______



V_c = 180 kV C_t = 70 nF

V_p = 45 kV L_t = --

I_p = ______ R_d = 1020

R_L = 300

Scale Factors

5/0	10
[illegible]	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μsec /Div.

Remarks [illegible]

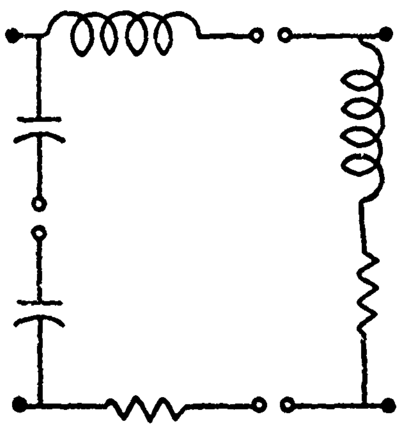
Instrumentation ______

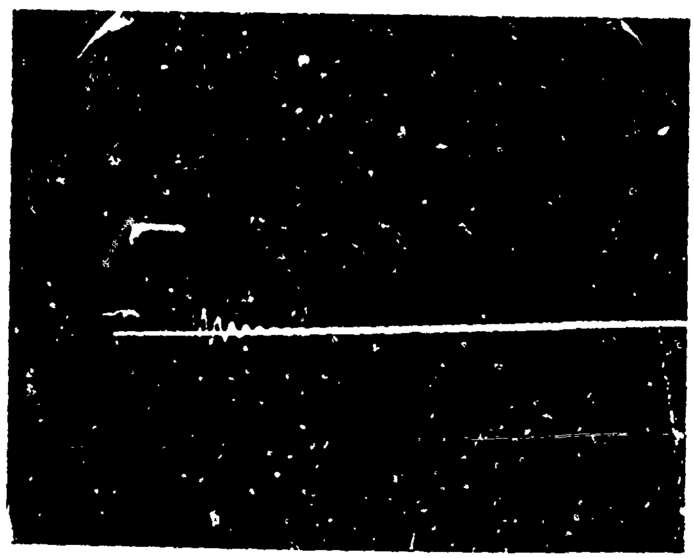
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 2-(Task ______ Date [illegible] 81

Test Item ______





V_c = 210 kV C_t = ______

V_p = 50 kV L_t = ______

I_p = ______ R_d = 1020

R_L = 300

Scale Factors

r/o	1?
RD	6??
[illegible]	250

Vert. 30 KV /Div.

Horiz. 5 nSec /Div.

Remarks HIGHER CHARGE TRACKS [illegible]

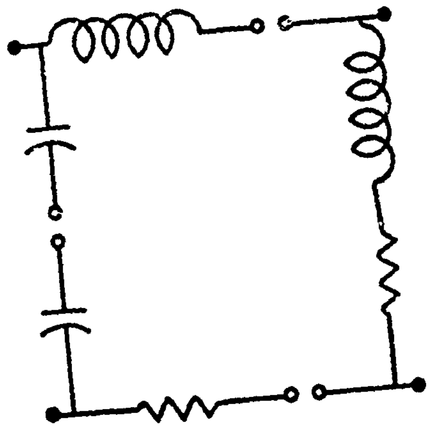
Instrumentation ______

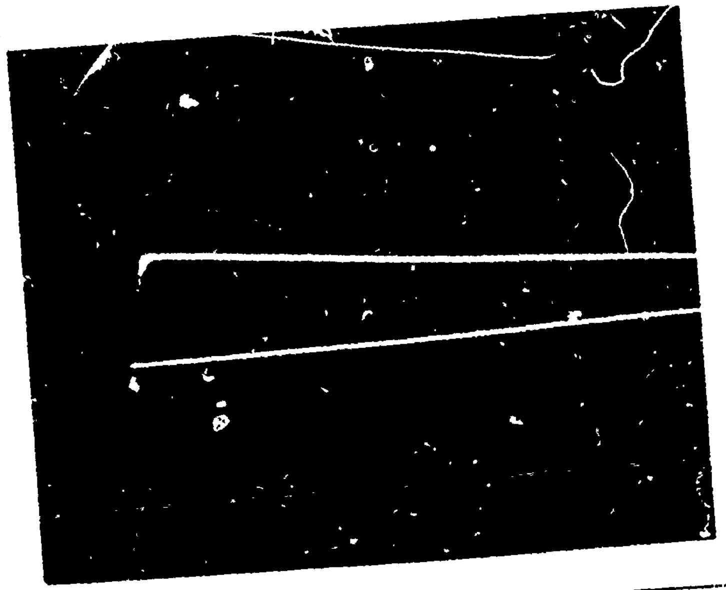
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 3a Task ________ Date 25 APR 81

Test Item ________





V_c = 220 KV C_t = 70 nfd

V_p = 56 KV L_t = ____

I_p = ____ R_d = 1020

R_L = 300

Scale Factors

T/0	10
RD	600
ATT'	250

Vert. 30 KV /Div.

Horiz. 5 μSEC /Div.

Remarks ADDED KAPTON TAPE TO ENDS OF INSULATOR ON LEFT

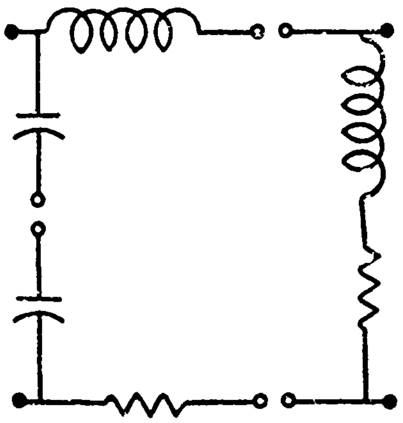
Instrumentation ________ Contract ________

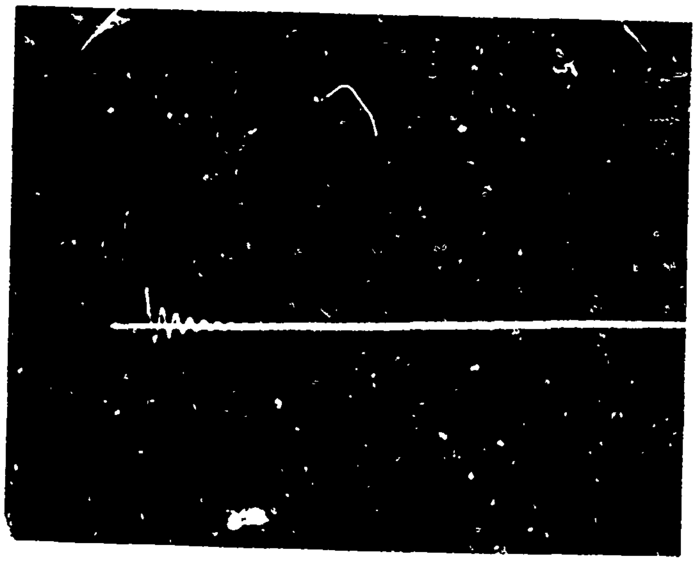
Test Supervisor ________

T/SSI TEST LOG

Test No. 4C Task ________ Date . / / /

Test Item ________





V_c = 270 kV C_t = 70 mfd

V_p = 61 kV L_t = ____

I_p = ____ R_d = 1020

R_L = 300

Scale Factors

F/o	10	
RD	600	Vert. 30 kV /Div.
[illegible]	250	Horiz. 5 μSEC /Div.

Remarks TRACKED ON OTHER SIDE

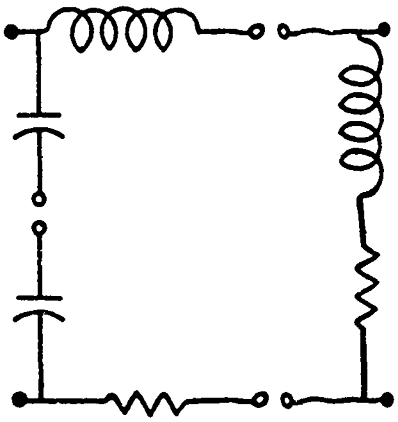
Instrumentation ________

Test Supervisor ________ Contract ________

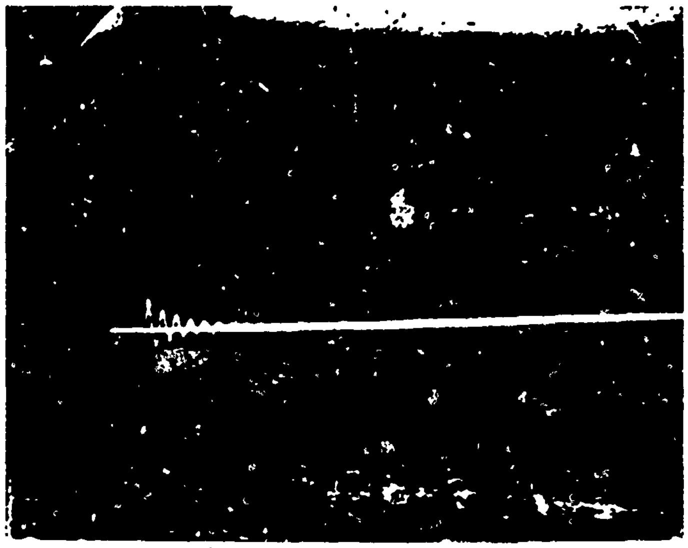
T/SSI TEST LOG

Test No. 5⊘ Task ______ Date 28 APR 81

Test Item ______



PS FO 10, RD 600, ATTN 250



30 KV/DIV 5 μSEC/DIV

V_c = 270 KV C_t = ______

V_p = 61 KV L_t = ______

I_p = ______ R_d = 1000

R_L = 330

Scale Factors

P/O	10
RD	600
ATTN	250

Vert. 30 KV /Div.

Horiz. 5 μSEC /Div.

Remarks TRACKED AGAIN - GOING TO ROD TO ROD

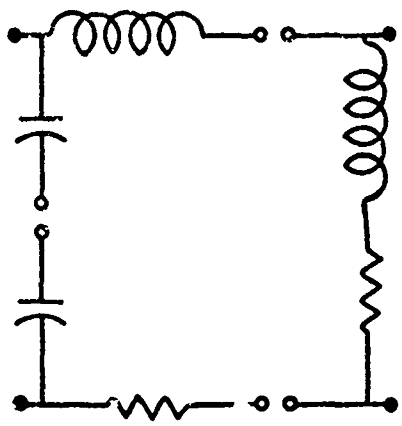
Instrumentation ______

Test Supervisor ______ Contract ______

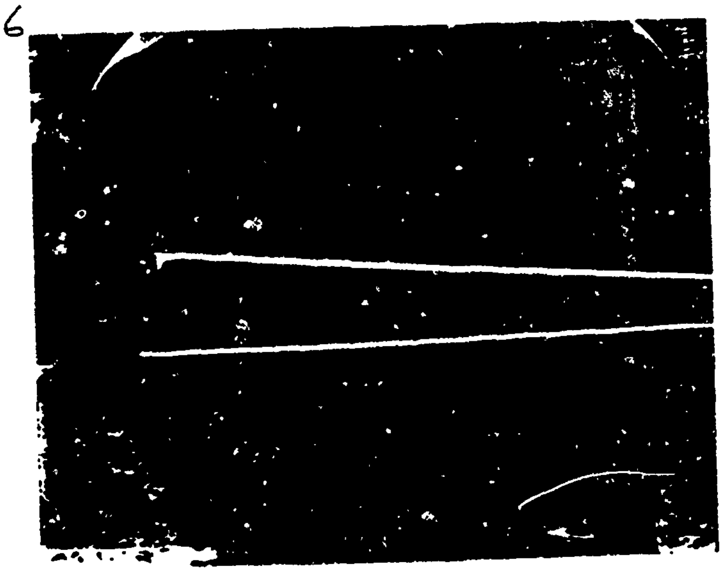
T/SSI TEST LOG

Test No. 60 Task ______ Date 28 APR 81

Test Item ______



6



V_c= 15.6 C_t = ______

V_p= 40 L_t = ______

I_p= ______ R_d= 1020

R_L= 300

Scale Factors

F/4	13
RD	665
Anvil	250

Vert. 30 KV /Div.

Horiz. 5 μsec /Div.

Remarks GND INSULATOR WRAPPED IN TAPE SQUARES, THEN PLASTIC SHEET ON TOP. WRAPPED OVER 2" STRIP ON MYLAR

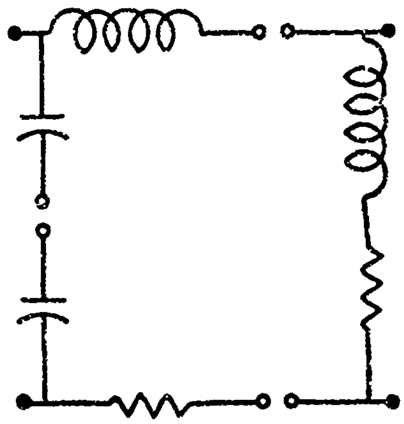
Instrumentation ______

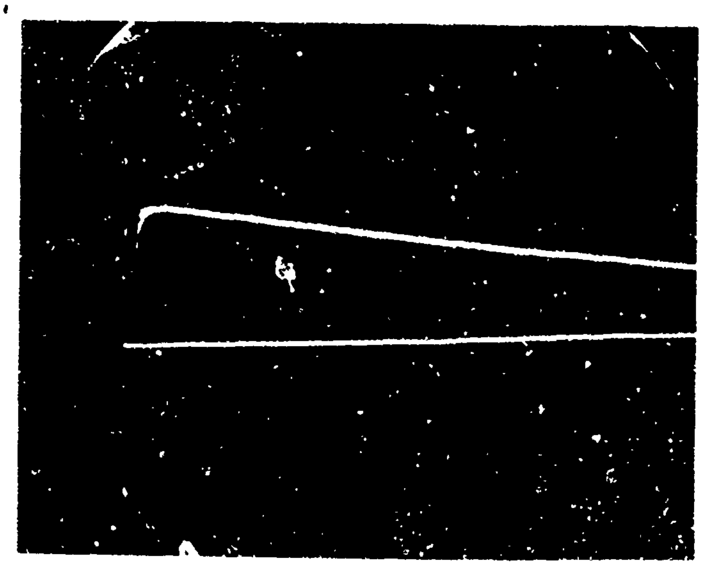
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 7A Task ____ Date [illegible]

Test Item ____





V_c = 270 C_t = ____

V_p = 65 L_t = ____

I_p = ____ R_d = 900

R_L = 400

Scale Factors

F/D	10
RD	600
A[illegible]N	250

Vert. 30 KV /Div.

Horiz. 5 μsec /Div.

Remarks ____

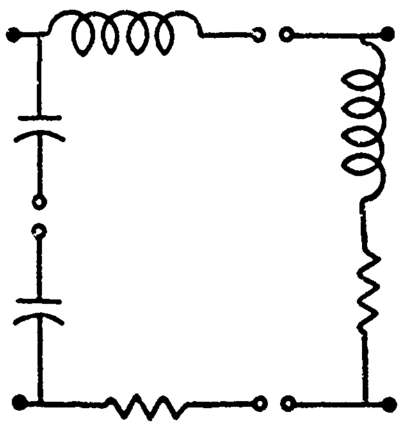
Instrumentation ____

Test Supervisor ____ Contract ____

T/SSI TEST LOG

Test No. 80 Task ____ Date 25 Nov 81

Test Item ____



V_c = 220 C_t = ____

V_p = 70 L_t = ____

I_p = ____ R_d = 420

R_L = 900

Scale Factors

5/0	10
R2	600
Ampl	250

Vert. 30 4V /Div.

Horiz. 5 μsec /Div.

Remarks ____

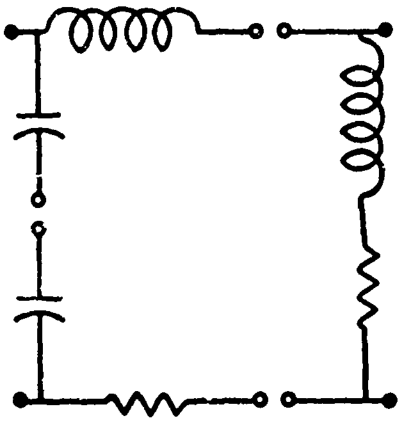
Instrumentation ____

Test Supervisor ____ Contract ____

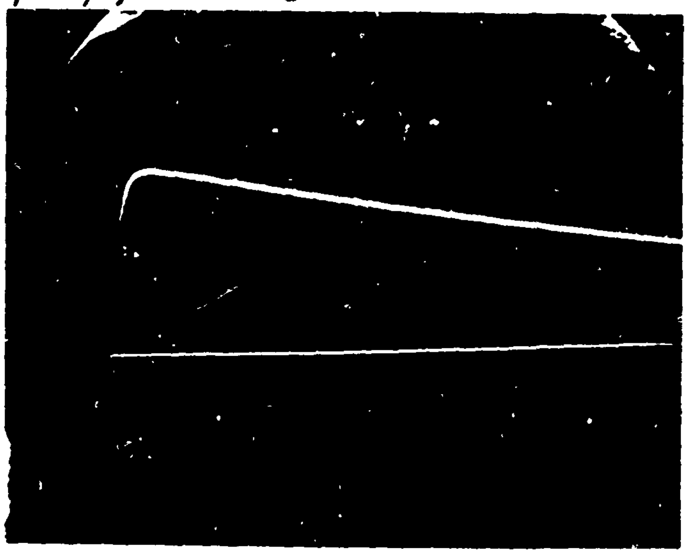
T/SSI TEST LOG

Test No. 9[illegible] Task ______ Date [illegible]

Test Item ______



59 F/0 10 R_D 600 [illegible] 250



20 kV/DIV 5 μSEC/DIV

V_c = ______ C_t = ______

V_p = 80 L_t = ______

I_p = ______ R_d = 900

R_L = 420

Scale Factors

F/0	10
R_D	600
[illegible]	250

Vert. 20 kV /Div.

Horiz. 5 μSEC /Div.

Remarks ______

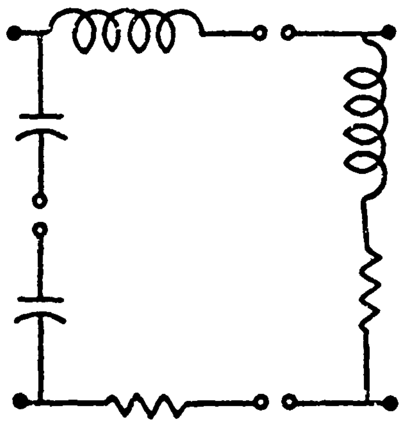
Instrumentation ______

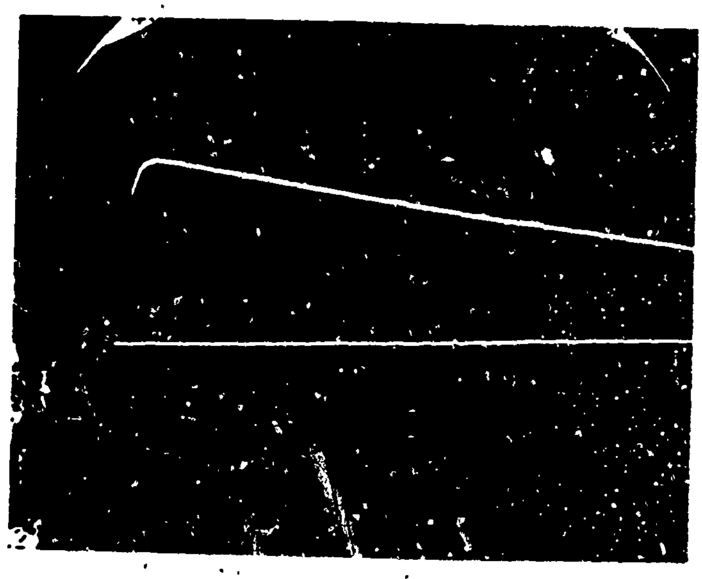
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 108 Task ______ Date 21 Apr 81

Test Item ______





V_c = ____ C_t = ____

V_p = 90 L_t = ____

I_p = ____ R_d = 70Ω

R_L = 420

Scale Factors

5/9	10
[illegible]	600
[illegible]	250

Vert. 30 kV /Div.

Horiz. 5 μSec /Div.

Remarks ______

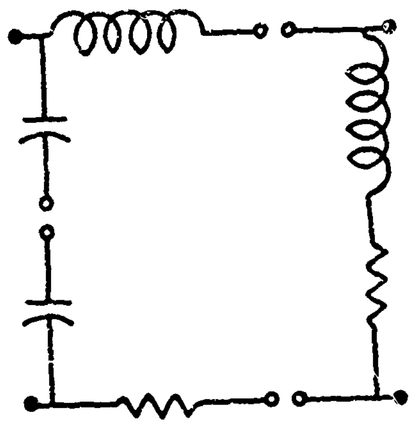
Instrumentation ______

Test Supervisor ______ Contract ______

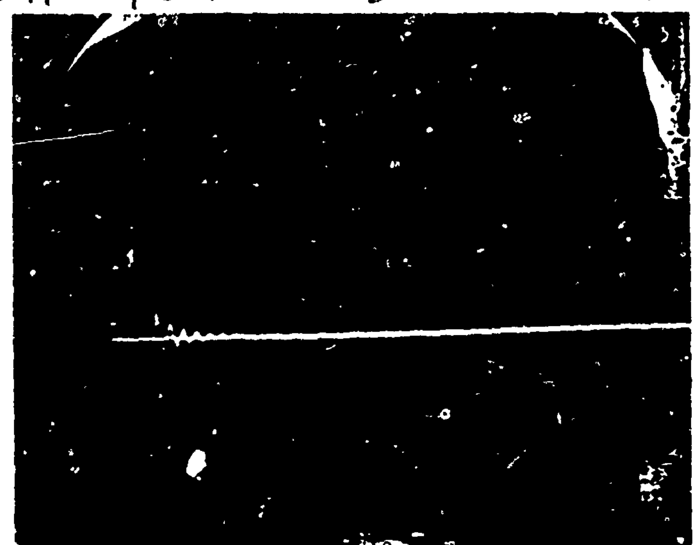
T/SSI TEST LOG

Test No. 11C Task _____ Date 31 Oct 81

Test Item _____



1#11 F0 10 RD 500 ATTN 500



60 kV/DIV 5 µSEC/DIV

V_c = 180 C_t = _____

V_p = 100 L_t = _____

I_p = _____ R_d = 600

R_L = 720

Scale Factors

F/0	10
RD	600
ATTN	500.

Vert. 60 kV /Div.

Horiz. 5 µSec /Div.

Remarks TRACKING

Instrumentation _____

Test Supervisor _____ Contract _____

APPENDIX E

PULSE TEST DATA FOR CABLE ASSEMBLY A-7 HIGH VOLTAGE

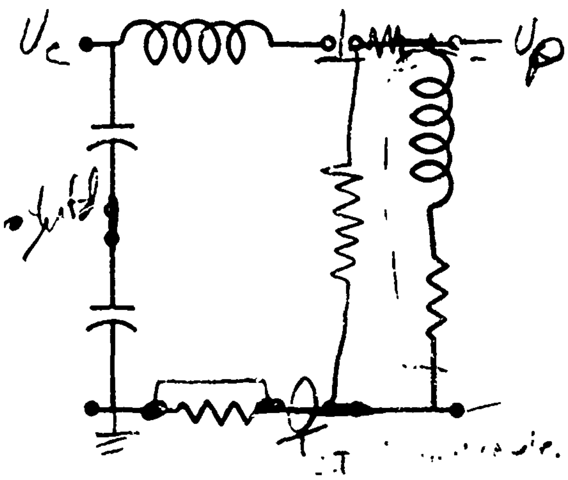
High voltage pulse tests for the cable assembly A-7, were concluded by Technology Scientific Services personnel in the Electromagnetic Hazards Test Facility, AFWAL/FIESL, Wright-Patterson AFB, Ohio.

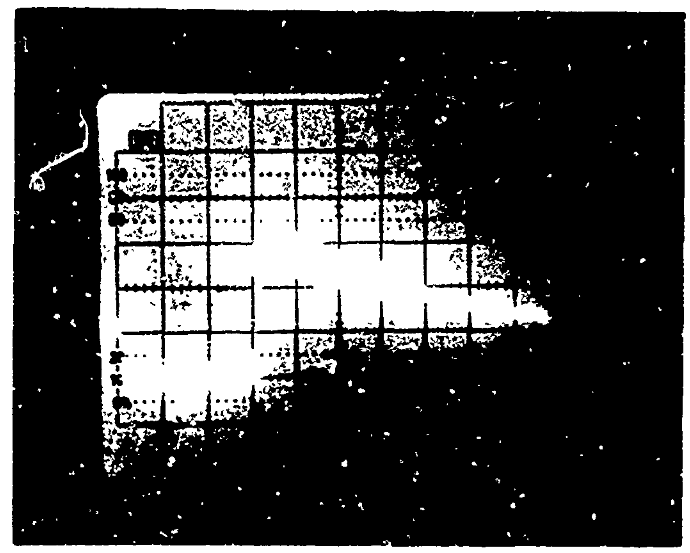
PRECEDING PAGE BLANK-NOT FILMED

T/SSI TEST LOG

Test No. Cal. Task ______ Date 30 DEC 81

Test Item APL- cable





V_c= 11 KV C_t = 4 uF

V_p= 11 KV L_t ≅ 3 uh

I_p= ______ R_d= 30 Ω

R_L= 5 Ω

Scale Factors

Probe	KV/V

Vert. 4 __ V /Div.

Horiz. 125 μS /Div.

Remarks Initial calibration test shot. Probe

The applied waveform is 1.5X50 usec

Probe was found to be ~~5%~~ 7% low.

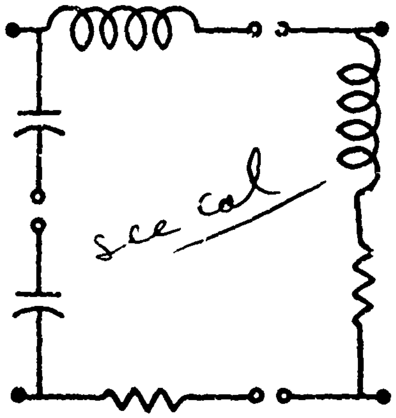
Instrumentation Biomation 610B - HP1744A: Camera - Tektronix - P6015

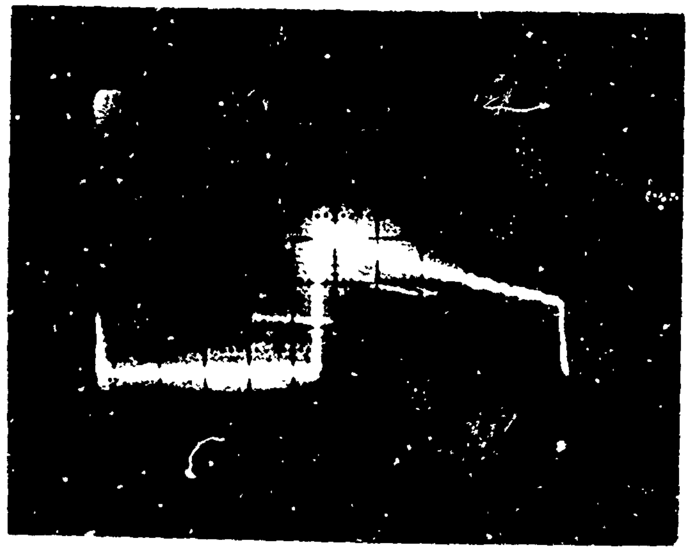
Test Supervisor JS Contract ______

T/SSI TEST LOG

Test No. 1 Task ________ Date 30 Dec 81

Test Item APL - Cable





V_c = 11KV C_t = ____

V_p = ____ L_t = ____

I_p = ____ R_d = ____

R_L = ____

Scale Factors

HV Probe 1K/1V

Vert. 11 V /Div.

Horiz. 12.5 μs /Div.

Remarks 1st shot attached to cable. - connector braided to gnd & braided shield bonded to gnd at same point.

No Breakdown

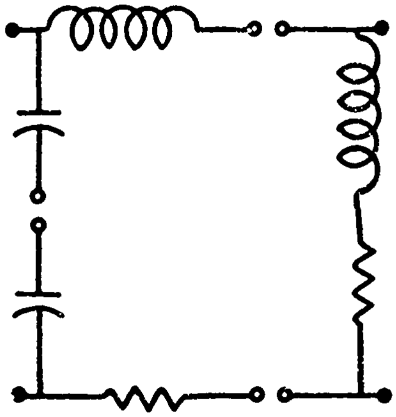
Instrumentation ________

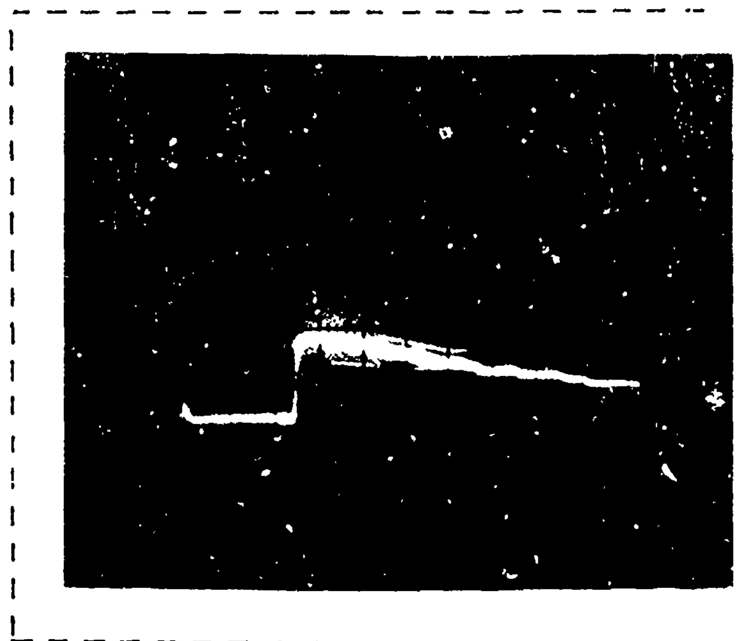
Test Supervisor ________ Contract ________

T/SSI TEST LOG

Test No. 2 Task ________ Date 30 Dec 81

Test Item APL - Cable.





V_c = 17KV C_t = ____

V_p = ____ L_t = ____

I_p = ____ R_d = ____

R_L = ____

Scale Factors

HV Probe 1KV/V

Vert. 10 V /Div.

Horiz. 12.5 μS /Div.

Remarks 1st shot at this level - waveform was clipped.
Waveform of second shot

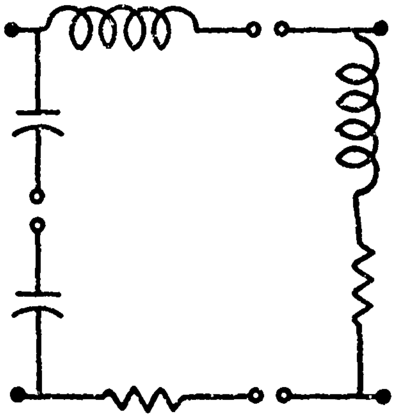
Instrumentation ________

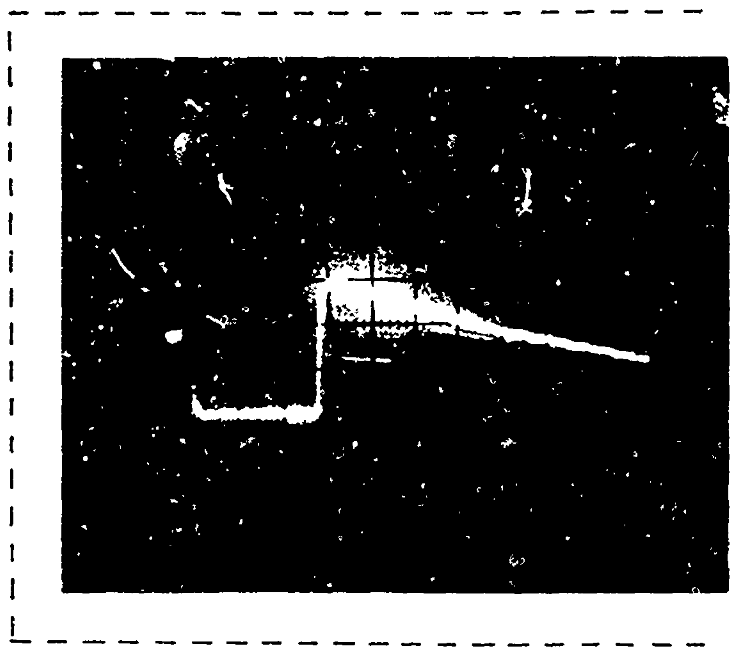
Test Supervisor ________ Contract ________

T/SSI TEST LOG

Test No. 4 Task ______ Date 30 Dec 81

Test Item APL - cable.





V_c = 28KV C_t = ______

V_p = ______ L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

HV Probe 1KV/V

Vert. 12 V /Div.

Horiz. 0.5 µS /Div.

Remarks ______

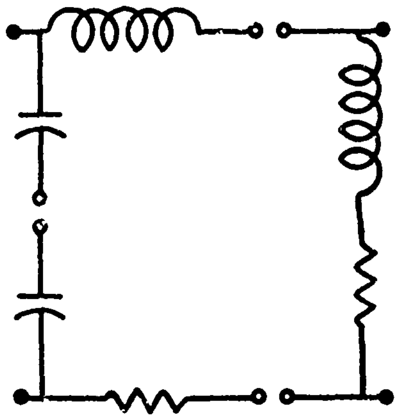
Instrumentation ______

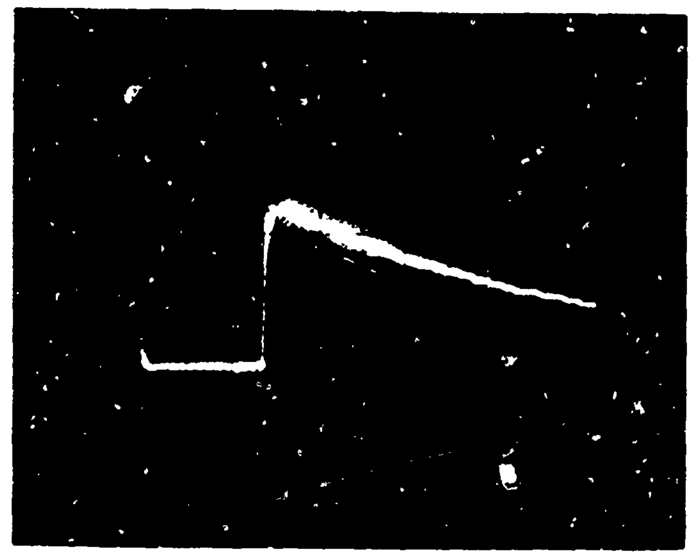
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 5 Task ____ Date 30 Dec 81

Test Item APL-Cable





V_c = ~~30~~ 34KV C_t = ____

V_p = 34KV L_t = ____

I_p = ____ R_d = ____

R_L = ____

Scale Factors

HV Probe 1KV/V

Vert. 10 V /Div.

Horiz. 12.5 μs /Div.

Remarks No breakdown [illegible] anywhere.

TESTING Just the connector		Testing Just the [illegible] cable.	
17KV - OK	#2	17KV - OK	
24KV - OK		24KV - OK	
29KV - "		29KV - "	#3
34KV = (35.5KV - ok)	35.3KV	35KV = " #2 shot ok.	34.1K ✓

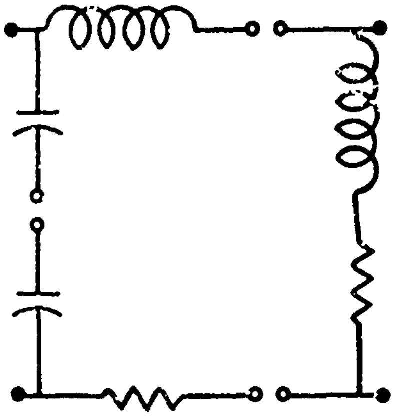
Instrumentation ____

Test Supervisor LS Contract ____

T/SSI TEST LOG

Test No. 6 Task ______ Date 30 Dec 81

Test Item [illegible] Cable



V_c = ~~34KV~~ 17KV C_t = ______

V_p = ______ L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

-1 Probe 1.4 kV/V

Vert. 10 V /Div.

Horiz. 12.5 μS /Div.

Remarks [illegible] scale factor [illegible]

[illegible] mV

after [illegible] - [illegible]

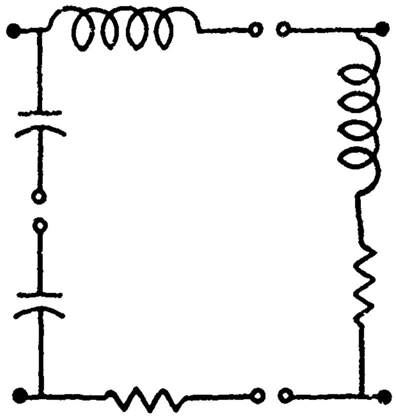
Instrumentation ______

Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 7 Task ______ Date 30 Dec 81

Test Item APL-Cables



V_c= 34kV C_t = ____

V_p= 31kV L_t = ____

I_p= ____ R_d= ____

R_L= ____

Scale Factors

1V/div | 20kV/V

Vert. 10 V /Div.

Horiz. 100 ns /Div.

Remarks Shot #1 w/ slightly over 2 ...

Shot #2 w/ charge (Vc) 37kV measure 34.7kV

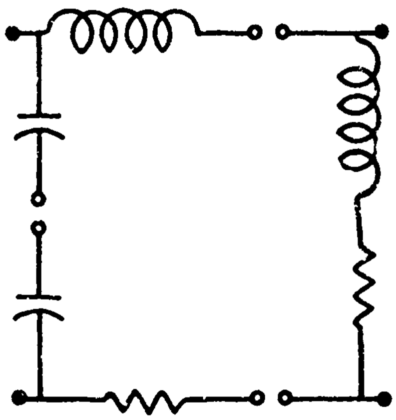
Instrumentation ______

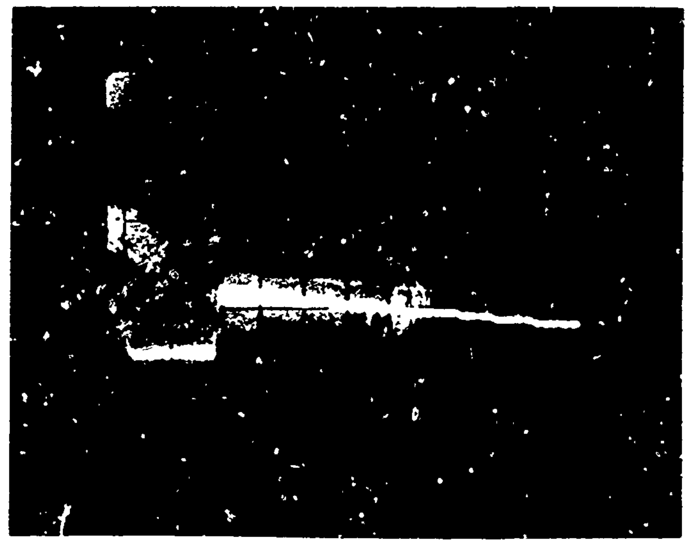
Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 8 Task ______ Date 30 DEC 81

Test Item APL - Cable





V_c = 17.5kV C_t = ______

V_p = 15.5kV L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

HV Probe 1.24kV/V

Vert. 0 V /Div.

Horiz. 12.5 µS /Div.

Remarks Cable #2

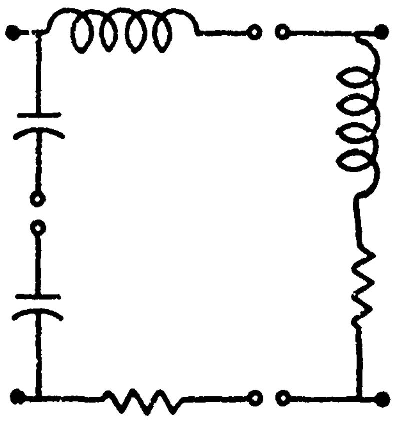
Instrumentation ______

Test Supervisor ______ Contract ______

T/SSI TEST LOG

Test No. 7 Task ______ Date 30 Dec 81

Test Item APL - Cable Cap



V_c= 34 kV C_t = ______

V_p= 30.1 kV L_t = ______

I_p= ______ R_d= ______

R_L= ______

Scale Factors

HV Probe 1.24 kV/V

Vert. 10 V /Div.

Horiz. 12.5 μs /Div.

Remarks ______

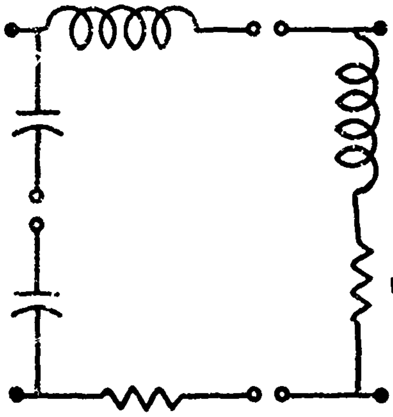
Instrumentation ______

Test Supervisor ______ Contract ______

T/SSI TEST LOG

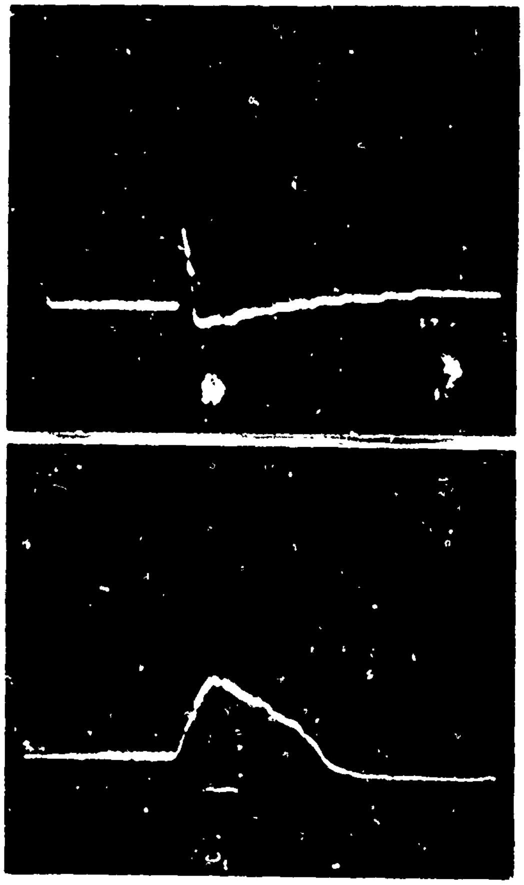
Test No. 10 Task ______ Date 30 DEC

Test Item APL- cables



10 V/DIV

12.5 μs/DIV



V_c = 50 kV C_t = ____

V_p = ____ L_t = ____ 10 V/DIV

I_p = ____ R_d = ____

R_L = ____ 1.25 μs/DIV

Scale Factors

[illegible] [illegible]

Vert. 10 V /Div.
Horiz. 1.25 μs /Div.

Remarks ____________________

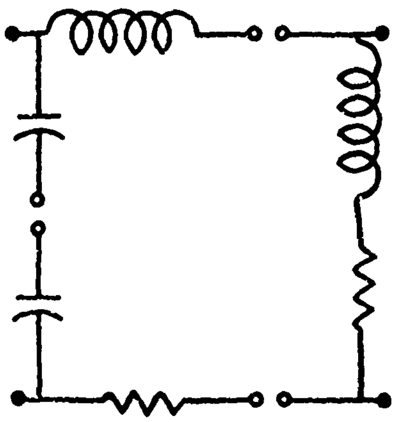
Instrumentation ____________________

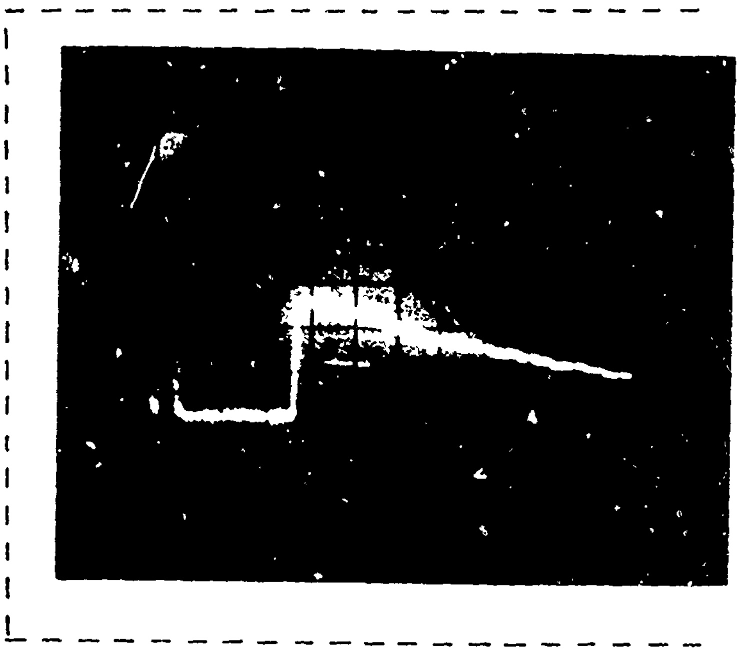
Test Supervisor ____________ Contract ____________

T/SSI TEST LOG

Test No. 13 Task ______ Date [illegible]

Test Item [illegible]





V_c = 73KV C_t = ______

V_p = ______ L_t = ______

I_p = ______ R_d = ______

R_L = ______

Scale Factors

1V Probe 1KV/V

Vert. 10 V /Div.

Horiz. 12.5 µs /Div.

Remarks ______

Instrumentation ______

Test Supervisor ______ Contract ______

APPENDIX F

DC PARTIAL DISCHARGE TEST DATA

The dc partial discharge test data were taken in the High Power Laboratory, AFWAL/POOS, Wright-Patterson AFB, Ohio using the equipment described in Paragraph 6.3.7.2.

A3 60 kV Cable — Applied Voltage | 32 Capacitor

Pulse Height Analyzer Channel	PC	60.2kV	50.5kV	40.3kV	30.2kV	99.3kV	80.2kV	60.2kV
76		5	4		1	2	4	1
77		4	2	2		1	9	2
78		8	5	3	3	1	2	2
79		6	1	1		1	7	2
80		7	1		1		8	3
81		7	3	2	1	1	4	2
82		7	1	1	1	2	6	2
83		3	1			3	6	
84		4	3	1	1	1	5	5
85		6	2	4			6	2
86		7	2	2	2		5	4
87		3	2	2	1	1	2	4
88		4	2	1	1	2	4	2
89		5	2	1		1	3	1
90		4	1	3	2	2	4	1
91		2	1	1	1		4	a
92		5	4				7	1
93	0.8	4	4	2	3	1	5	4
94		2	1	3	1	1	3	
95		5	1	1	2		3	
96		4	4		1	4	1	3
97		5	2		3	1	5	3
98		7	2	3		1	3	
99					2		4	1
100		3	1	1	2	2	1	2
101		3		1	2	1		
102		2	4	1	1	1	1	2
103		2		1			3	2
103		2	2	1			2	2
104		1	2		1	1	8	1
105		2		1	1	1	3	
106		4	8	1			2	1
107		2	4	1	1		3	
108		5	4	1			4	2
109		3	1				6	4
110		1		2			7	1
111		3		1		1	2	
112		6	4		1	1	4	
113		3	3	1			4	2
114		3		1	4		1	2
115		1	1		2	3	3	
116		2	3			3	2	1
117		3	3	1	1		7	2
118		4	1	1		3	3	3
119		8	1	3	1	1	5	
120		1		1	3		3	1
121	1.0	2	1	7		4	8	1
122		1					6	
123		3		1	1		5	2
124		-			1	1	2	1
125		2		2	1	1	3	2
126		-	1		1		1	1
127		4	2	1		1	1	
128		2	2	1		3	6	1
129		2	2				4	
130		2	1			1	4	
131		2	2	1			2	1
132		3	2			1	3	
133		2	1	1			3	2
134		3	1			1	3	
135		4	1	1				1
136		3	1			1	2	1
137		2		2			1	
138		3	1	1	2			2
139		2	1	1			3	
140		2		2		2	3	
141		1	1					
142		1	1				1	
143		1	1		1	1		
144		4		1			3	1
145		3	2	1	1	1	2	
146		1		1		1	2	1
147		1	2	1	1	1	1	1
148		1			1	2	2	2
149		1	1	2		1	2	2
150		1	1	1	1	2	3	1

Pulse Height Analyzer Channel	PC	A3 60 kV Cable Applied Voltage 60.2kV	50.3kV	40.1kV	30.2kV	B2 Capacitor 49.7kV	30.2kV	60.2kV
151		3		1			1	
152		3	2			1	3	1
153		3					4	
154		2	2			4	1	2
155			1	2		1	2	
156		3		1	1		6	
157		4	1	1	1	1	1	1
158			2	1	1	3	1	
159					1		4	1
160		2	1			1	5	2
161		1		1	1	1		
162		2	2	1	2	2		
163			1	1	3	2	1	1
164		1	2		1	2	2	1
165		1	1				1	1
166				1			1	1
167		1				1	1	1
168		2			1	2	3	
169		1				2	3	
170						2	4	
171					2		6	
172					1	1	1	1
173		2	2			1	2	1
174				1		1	3	1
175		3		2		2	6	2
176		1	1	2	1		1	
177		2		1		2	3	1
178		5		2		1	4	
179		1	2				1	1
180		2	1				2	1
181		2	1					
182					2		2	
183		1	3	1	1	2	1	
184		2	2	3	1	7	1	
185			1		2		2	
186		3	1			1	1	
187			2		2	1	2	1
188			1				3	
189							3	
190		1					3	
191								
192		3	1					1
193		1				2	2	
194						1	1	1
195								1
196		3	2			2	2	1
197		2						1
198		1	2			1	1	
199		1	1				1	
200		3		1			1	
201				1	2	2		1
202			2	1	1		1	1
203			1			1		
204		1	1	1			2	1
205			1				2	
206		2				2		
207		2	1				1	2
208		1	1	1				
209				2			1	1
210		2		2	1	1	1	1
211		1						
212		1	1	2			1	
213		1	1	1	1	1	1	
214		2					1	
215							3	
216					1			
217		1					2	
218		4	2			2		
219			1		1			2
220					1			
221		2	1				1	
222				1			1	1
223							1	1
224		1					1	
225				1			1	

		A3				B2		
Pulse Height Analyzer Channel	PC	60 KV Cable Applied Voltage 60.2KV	50.3KV	40.3KV	30.[illegible]	Capacitor 40.7KV	50.[illegible]KV	60.2KV
226			1		1		1	
227		1						
228						1	3	2
229				2	2	3	1	1
230		2		1	1	1		
231							1	
232		1	1					
233			2	1			4	
234			1					
235							3	
236		1		1				1
237					1			
238		2				1	2	
239			1	1		1		
240						1		1
241		2	2					
242		2	1	1			2	
243							2	1
244					1			
245		1				1	5	
246				1		1		
247		1		1			1	
248			1	1				
249		2		1				1
250				1			1	1
251	2	1	1					
252					1		2	
253				2				
254		2		1		1	3	
255				1		2	2	1
256		2	1	1			3	
257			1		1	1		
258			1			1	3	
259						1		
260		1	1			1	1	
261								
262		1		2	1	3	1	2
263				2			1	1
264							1	
265			1		1	2		
266		1			1		2	
267							1	
268		1					1	1
269						1		
270			1			2	3	
271		1						
272			1			2	1	
273							1	
274		2		1				
275		3		1				1
276								
277							1	1
278								
279						1		
280				1	1		1	1
281			1		1			
282								
283		1						2
284		1						1
285				1			4	
286								1
287		1						1
288		1		1		2	1	
289				1	1			
290		1		2				1
291		1		1	1			
292		1		1	1			
293				1				
294				1				
295							1	
296			1		1		1	
297			1		1			
298							1	
299			1		1	1	1	
300			1	1		1	2	1

Pulse Height Analyzer Channel	PC	A3 60 kV Cable Applied Voltage 60.2 kV	50.5 kV	40 kV	30.2 kV	B2 Capacitor 49.7 kV	50.2 kV	60.2 kV
301						1		1
302								
303		1					1	
304			1				1	
305		4						
306						1		
307		1	1			1		
308		1						
309			1	1				
310		1	1				1	
311							2	
312					1			
313		1				1		
314								
315		2			1	1		
316		1						
317							1	
318						1		1
319		1				1		
		2						1
321		1					1	
322		1	1		1	1		
323		1			1			
324		1						1
325		1				1	2	1
326			1				1	
327							1	
328		1				1		
329		1			1	1	1	
330							1	1
331			1					
332		1						
333						1		
334						1		
335		1						
336						1	2	
337			1				1	
338								
339		2			1			
340		1	1		1	1		
341		1		1				
342		2				1		
343				1				1
344					1	1	1	1
345				1				
346			1				1	
347					1			
348							1	
349		1	1		1			
350		1						1
351			1					
352			1					
353				2				
354								
355	3.0		1					1
356							1	
357		1			1			
358								
359		1		1		1		
360		1				1		
361		1	1					
362								
363								
364								
365							1	
366			1					
367								
368								
369		1						1
370								
371			1					
372							1	
373							1	
374						1		
375								1

Pulse Height Analyzer Channel	PC	A3 60 kV Cable Applied Voltage 60.2 kV	50.5 kV	40.3 kV	30.2 kV	B2 Capacitor 99.? kV	80.2 kV	61.2 kV
376								
377		1			1		1	
378								
379						1		
380		1		1	1	1	1	1
381			1	1				
382								
383								
384								
385		1	1					
386		1		1				
387								
388								
389								
390		2						
391			1					
392						1	1	
393								
394		1		1				
395					1		1	
396								
397			1			1		1
398		1	1		1			
399		1		1				
400						1		
401		1			1			
402			1	1				
403			1					
404								
405				1				
406			1					
407								
408					1		1	
409								
410		1						
411								
412								1
413		1					1	
414								
415							1	
416							1	
417		2				1		1
418							1	
419			1				1	
420		1	1	1		1	1	1
421								
422							1	
423					1			
424				1				
425								
426				1	1		1	
427			1					
428								
429								
430					1			1
431								
432				1		1		
433								1
434		2			1			
435		1						
436								
437								
438					1			
439								1
440							1	
441								
442							1	
443		1					1	
444								
445					1			
446								
447							1	
448							1	
449								
450								

Pulse Height Analyzer Channel	PC	A3 60kV Cable Applied Voltage				B2 Capacitor			C1 Capacitor
		60.2kV	50.5kV	40.3kV	30.2kV	79.7kV	28.2kV	10.1kV	
451									
452							1		
453									
454									
455									
456									
457		1	1						
458			1						
459			1						
460			1						
461									
462			1				1		
463						1	1		
464			1						
465		1							
466								1	
467									
468							1	1	
469								1	
470							1		
471									
472							1		
473		2							
474									
475				1			1	1	
476		1							
477									
478									
479									
480			1						
481									
482		1					1		
483									
484									
485				1					
486									
487							1		
488									
489									
490									
491		1		1					
492		1							
493							1	1	
494				1				1	
495									
496									
497									
498			1				1		
499									
500									
501									
502									
503			1						
504								1	
505							1		
506				1		1	1		
507									
508									
509			1				1		
510							1		
511	4							1	
512				1					

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